

T AN ECONOMIC ANALYSIS OF THE DEMAND
FOR RESOURCES AND THE SUPPLY OF
OUTPUT IN SOUTH AFRICAN AGRICULTURE /

By

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CONTENTS

<u>CHAPTER</u>	<u>PAGE</u>
1. INTRODUCTION.....	1
2. DESCRIPTION OF THE SOUTH AFRICAN FARMING INDUSTRY.....	7
2.1. Physical and natural resources.....	7
2.2. The output mix.....	15
2.3. Agro-economic classification of land.....	18
2.4. Economic interference in the resource and product markets.....	26
2.4.1. Price interference in the resource market.....	26
2.4.1.1. Fertilizer subsidies.....	26
2.4.1.2. Feed and livestock subsidies.....	28
2.4.1.3. Loan schemes.....	29
2.4.1.4. Assistance under the Soil Conservation Act.....	30
2.4.1.5. Indirect assistance through government departments, other than Agricultural Economics and Marketing.....	31
2.4.2. Interference in the product markets.....	32
2.4.2.1. Schemes under the Marketing Act.....	32
2.4.2.2. Subsidisation of products.....	34
2.4.2.3. Product prices in South Africa compared with world prices.....	35
2.4.3. The effects of economic interference on national welfare.....	36
2.4.4. Interference in the market for farm labour.....	39
2.5. Tenure in South African Agriculture.....	44
3. TRENDS IN RESOURCE USE.....	48
3.1. Output per unit of input.....	48
3.2. Resource substitution in agriculture.....	50
3.3. Price trends.....	56
3.4. Farm income.....	65
3.5. Structural changes in farm size.....	67
4. AGGREGATE AND REGIONAL PRODUCTION FUNCTIONS.....	72
4.1. Aggregate production functions.....	72
4.1.1. Aggregate cross sectional production functions...	72
4.1.1.1. Estimation of the production function using principal components.....	83

CHAPTERPAGE

4.	4.1.2. Aggregate time series production function based on factor shares.....	87
(contd.)	4.1.2.1. Estimation of elasticities by ordinary least squares.....	90
	4.1.2.2. Estimation of elasticities by autoregressive least squares (ALS).....	91
	4.1.3. Evaluation of factor shares and cross sectional elasticities.....	94
	4.1.4. Elasticities of substitution between factors....	95
	4.1.5. Elasticity of demand and supply of inputs.....	98
	4.1.5.1. Theory on derived factor demand.....	98
	4.1.5.2. Practical implications.....	104
	4.1.6. Value of the marginal product and demand curves of a factor (labour) for the Agricultural Industry under competitive conditions.....	108
	4.1.7. Reallocation of resources in agriculture.....	111
	4.1.7.1. Marginal products.....	111
	4.1.7.2. Minimum cost input levels.....	112
	4.1.7.3. Optimum resource allocation.....	116
	4.2. Regional production functions.....	118
5.	RESOURCE DEMAND FUNCTIONS FOR OPERATING INPUTS AND LABOUR...	127
	5.1. The construction of a resource demand function.....	127
	5.2. Demand functions for fertilizer.....	130
	5.2.1. Introduction.....	130
	5.2.2. Discussion of variables.....	133
	5.2.3. Results.....	136
	5.2.3.1. Aggregate demand functions for fertilizer with plant nutrients unweighted for the period 1952-1966.....	136
	5.2.3.2. Aggregate demand functions for fertilizer with weighted plant nutrients.....	141
	5.2.3.3. Aggregate demand function with plant nutrients unweighted for the period 1943-1967.....	144
	5.2.3.4. Provincial model.....	149
	5.3. Demand functions for feed.....	153
	5.3.1. Aggregate demand function.....	153
	5.3.2. Provincial model.....	153
	5.3.3. Aggregate demand for maize used as feed.....	156
	5.4. Demand for fuel and lubricants (provincial model).....	161
	5.5. Demand for hired farm labour.....	163

CHAPTERPAGE

5.	5.5.1. Aggregate demand function.....	163
(contd.)	5.5.2. Provincial model for Bantu regular labour.....	167
6.	RESOURCE DEMAND FUNCTIONS FOR FARM MACHINERY.....	169
6.1.	Some theoretical aspects of investment.....	169
6.1.1.	Income.....	169
6.1.2.	Interest rate.....	171
6.1.3.	Other assets.....	172
6.1.4.	Prices of inputs.....	173
6.1.5.	The acceleration principle.....	174
6.1.6.	The residual funds, echo effect and senility effect theories of investment.....	175
6.1.7.	The investment model.....	175
6.2.	Demand functions for farm tractors.....	176
6.2.1.	Aggregate model.....	176
6.2.2.	Provincial model.....	181
6.3.	Demand functions for new machinery, implements and tractors (aggregate model).....	186
6.4.	Demand functions for new machinery and implements.....	187
6.4.1.	Aggregate model.....	187
6.4.2.	Provincial model.....	189
6.5.	Demand functions for lorries.....	191
6.5.1.	Aggregate model.....	191
6.5.2.	Provincial model.....	195
6.6.	Demand functions for pumping equipment.....	196
6.6.1.	Aggregate model.....	196
6.6.2.	Provincial model.....	197
6.7.	Demand functions for spare parts.....	198
6.7.1.	Aggregate model.....	198
6.7.2.	Provincial model.....	200
7.	DERIVATION OF A PRODUCT SUPPLY ELASTICITY FROM FACTOR DEMAND ELASTICITIES REPORTED IN CHAPTERS 5 AND 6.....	202
8.	DISCUSSION AND CONCLUSIONS.....	204
9.	SUMMARY.....	218

	<u>PAGE</u>
LITERATURE CITED.....	227
APPENDIX.....	275
ACKNOWLEDGEMENTS.....	(1)

CHAPTER 1.

INTRODUCTION

For a thorough understanding of the agricultural industry and its related problems more must be known about the complex integrated system of product and resource markets. Until fairly recently research was directed towards an analysis of the product market neglecting the equally important factor market. The agricultural economic system can fully be described by the supply and demand functions for factors and products. These relationships are interdependent and can be described by a set of simultaneous equations. The neglect of any one of these relationships may result in the implementation of policy measures that misleads the objectives of policy.

An integrated model of product and resource markets is also necessary because product markets determine gross income, resource markets determine expenses and the two markets determine the net income from farming. A number of practical examples may be advanced illustrating the interdependence between these markets. When product prices are fixed at a level higher than free market equilibrium, this fixing may have an important bearing on factors such as the number of farm workers employed and the quantity of fertilizer used. On the resource side, a subsidy on fertilizer increases the optimum level of fertilizer use, shifts the product supply to the right, and results in increased production and lower product prices under competitive conditions.

In the interest of social welfare and economic efficiency, government policies to control output, to increase farm income or to fix product prices cannot ignore the resource structure.

As far as is known, Griliches (1958) estimated the first resource demand model for fertilizer in the United States as a function

solely of the price of fertilizer (49). In all the subsequent resource demand studies reported by Griliches, the models were of a simple nature with the main interest centred on the prices of the inputs (50) (51) (53). During the early nineteen-sixties a number of other researchers entered the field and they tried models with more variables, attention being given to variables other than the prices of the inputs concerned. The following workers, apart from Griliches, may be considered to have made important contributions: Tweeten (132), Schuh (118), Minden (101), Cromarty (21), Heady and Tweeten (76), and Wallace and Hoover (145).

The general objective of this study is to describe and analyse the resource structure of the agricultural industry in South Africa. The resource structure is defined by Tweeten (132) as "the systematic framework of institutional, behavioural and technological relationships which determine output, efficiency and returns (income) in agriculture". The attempt is here made to derive quantitative estimates of the parameters as they apply in South Africa, using cross-sectional and time series data.

The first objective is to construct a cross-sectional production function for the agricultural industry. For this purpose data are obtained from the comprehensive 1959/60 agricultural census, using magisterial districts as observational units. The Bureau of Census undertakes a comprehensive survey every five years and intervening years since 1960 are not available. Production functions are constructed for each of the Agro-economic Regions as defined by the Agro-Economic Survey in order to compare the marginal products of resources. A macro production function with nine inputs is also fitted on time series data (1949/50 - 1965/66) making use of autoregressive least

squares. Various economic relationships pertaining to the problem of resource adjustment such as factor demand elasticities, are derived from this technical relationship.

A second objective is to estimate time series demand functions for the major farm resources. These models measure the effect of variables such as the price of a factor, the incomes of farmers, prices of other factors and the asset positions of farmers on the amount purchased of that factor. It is, for example, of interest to know the effect of a good crop or a drought on the purchases of farm resources. Also, what will be the effect of a five per cent cut in fertilizer price, or a fertilizer subsidy, or a five per cent increase in product price on the total amount of fertilizer bought by the agricultural industry? Distributed lag models are incorporated in the demand relationships, where possible, to measure the lag in response to price and income changes. From the factor demand elasticities a product supply function is derived.

The study is of a positivistic nature. The assumption of positivistic models is that there exists a significant measure of repetitiveness in mass behaviour. If the underlying conditions in a situation are repeated, then the dependent variables can be predicted with a reasonable degree of accuracy. The assumption of profit maximization was, however, made in certain cases when secondary results were derived from basic results, viz. in determining the optimum allocation of resources or in deriving the product supply function from factor demand elasticities.

In the selection of the models reported, high priority is given to the predictive nature of meaningful economic relations and on the ability to explain the past. Some variables may be

classified as potential policy instruments and the structural model provides the basis for evaluating the effectiveness of various policy instruments like product or input prices for attaining policy targets such as lower production. Policy aspects will be further investigated.

Governments implement agricultural policy, either to provide gains to producers, or to benefit consumers. According to Heady (70, pp. 14-15) these policies fall under two categories: (a) developmental policy and (b) compensation policy. The purpose of developmental policies is to increase product supply. The shift of the supply function reduces the real price of food to consumers. In South Africa policies which are concerned with the subsidization of resources and with research are the most important in this respect. The total subsidies and rebates on resources have increased from R1.6m in 1948-50 up to R17.8m for 1968 (24). This is particularly important in the case of fertilizer, where the subsidy increased to R14m in 1968. With a total expenditure on fertilizer of about R55m (24), this subsidy must have an important allocative effect. Through the various loan schemes available to farmers, the cost of credit is also reduced, shifting the supply curve of capital and farm output to the right. A considerable amount of money is spent annually on research. The development of higher yielding varieties, for example hybrid maize, and the combating of insects and pests, are the fruits of research both locally and abroad. A positive shift in the production function through research also shifts the commodity supply curve to the right, reducing consumer prices under conditions of no product price interference from the State.

Another developmental policy that deserves mention is the assistance rendered by the State, under the Soil Conservation Act.

In 1969 the legislative power of this Act was extended for all practical purposes to all agricultural land (114).

For the firm, the immediate end of these developmental policies is to increase farm income through increased production or lower factor cost. For the industry with a product demand elasticity of less than one, the result will be a reduction of total income and consequently also net income.

While the effect of the developmental policy is to move the product supply curve to the right, the compensation policy attempts to increase commodity prices and farm income, by restraining supply, or increasing the demand for products. These policies may run contrary to one another. In the following industries the production is controlled completely or partially; sugar, wattle, wine and milk. While the subsidies on resources have the effect of moving the product supply to the right the production restrictions have the effect of shifting the supply to the left.

More than 70% of the total agricultural production is marketed through the various Control Boards which have been granted extensive powers through the Marketing Act (113, p. 3), as for example the power to fix maximum and minimum product prices.

The "surplus" problems in some of the industries in South Africa, for example maize, Kaffircorn and dairy are a result of the subsidization of resources by the State, the fixing of product prices at arbitrarily high levels, and by-products of technological development. The inelastic product demand aggravates this problem which may be viewed as one of the more important agricultural problems of the next few decades.

Research may bring forth increased production without

significantly increasing total cost. Gains from research are over an indefinite period of time, and even if it is done at a cost, it is difficult to support a case for discontinuing it.

The effects of price interference in product and resource markets are, however, viewed in a different light. Here the "surplus" problem may be seen as a direct result of the State intervention in the product and resource markets.

The structural parameters presented in this study should cast some light on the possible effects of different policies. The fixing of product prices and the subsidizing of resources must have a stimulating effect on agricultural output through adjustments in the resource markets.

The present restrictions imposed by the State on the free mobility of hired Bantu labour can also be expected to reduce labour cost to the farmer when the supply of labour is kept on the farms at levels higher to what it would have been had free mobility existed. This policy in the main is implemented as a part of the political policy of the State where the prime motivation is not economic.

CHAPTER 2.

DESCRIPTION OF THE SOUTH AFRICAN FARMING INDUSTRY

The Republic of South Africa, lying between 22° and 35° South Latitude, covers an area of 1,222,000 square km.^{*}, the total area being 13% of the area of the United States and five times the area of the United Kingdom (36).

The average gross value of agricultural output in South Africa for the period 1963 - 1967 amounted to R1,043m (31, p. 84). For the same period, agricultural exports as a percentage of total exports made up 45% of total exports, excluding gold and this percentage has remained relatively constant for the last two decades (11). The share of agriculture, forestry and fishing declined to 10.6% of the gross domestic product in 1963 - 1966 (31, p. 82), while the percentage of total population living in rural areas declined from 76.4% in 1904 to 53.3% in 1960 (11). In 1960 16.4% of Whites, 31.7% of Coloureds, 16.8% of Asiatics and 68.2% of Bantu lived in rural areas, with Bantu reserves included as Bantu rural areas (11). During 1962 47% of the agricultural output was delivered to secondary industries (33), and it is evident that the South African agriculture plays an important rôle in the economy.

2.1. Physical and natural resources

Two-thirds of South Africa is dry and suited only for extensive systems like cattle ranching and sheep farming. Production in the rest of the country, which is intensively farmed, tends to be hampered by poor soils and irregular rainfall (122, p. 2).

About 80% of the Republic's area is a summer rainfall region with dry winters. It is generally accepted that 64 cm.^{**} of rainfall

* 1 square km = .3861 square mile. ** 1 cm = .3937 inches.

is the absolute minimum necessary to ensure the successful cultivation of crops in the summer rainfall area.. Only one-third of this area has a precipitation of more than 64 cm., with the result that production is limited to a small section (40, p. 62). The rainfall is not only erratic from year to year, but shows great variations within a production season. This explains to a large extent the unstable production pattern which is a characteristic of South African agriculture (40, p.62).

Approximately 130,000 square km. in the Western Cape is a winter-rainfall zone and 40,000 square km. in the south has rain all the year round (81, p. 29). The climate varies from "Mediterranean" in the south-west to near tropical in the north-east, enabling the production of a wide range of crops (81). The land rises fairly steeply in the east from sea-level to a high interior plateau of about 1,800 metres.* The possibilities of intensive farming are limited because the greater part of the country is mountainous and therefore not arable, and the lack of natural water resources limits expansion in the areas where arable soil with a high potential is still found. According to Table 2.1 the arable land area is approximately 10% of total area and it is estimated that only a further 5% of the land surface is really suitable for arable farming (81, p. 30) (95, p. 3). About 50% of the agricultural output is produced at present on the 10% of arable land.

The percentage of arable land in South Africa is relatively small in comparison with other countries, but the proportion available for permanent meadow and pasture in South Africa is more than that of other countries.

The area under irrigation in South Africa should increase considerably on completion of the Orange River Scheme. It is

* 1 metre = 3.2808 feet.

estimated that about 42% of the country's potential irrigable land is at present under irrigation (121, p. 13).

Siertsma (121) attributes the relatively low percentage of arable land which will eventually be used for irrigation farming, to the following factors:-

- "(a) In the areas where land is still available, natural water supplies for irrigation are limited.
- (b) In areas where reasonable quantities of water are still available land suitable for irrigation farming is limited. This water can only be used for agricultural purposes by piping it over long distances at high cost.
- (c) The competition for water from the industrial sector may be expected to be more severe in future".

TABLE 2.1. APPORTIONMENT OF TOTAL AREA* FOR SOUTH AFRICA (WHITE AREAS), UNITED STATES, UNITED KINGDOM, AUSTRALIA AND FRANCE.

Land utilization	South Africa (1960)	United States (1964)	United Kingdom (1966)	Australia (1965)	France (1965)
	Thousand hectares				
Total area	108,350	936,322	24,403	768,680	54,703
Agricultural area and forested land	90,291	735,825	21,416	521,549	46,367
Arable land and land under permanent crops	10,024	179,839	7,480	37,150	20,542
Permanent meadow and pasture	79,186	260,362	12,107	448,687	13,459
Forested area	1,081	295,624	1,829	35,711	12,363
Irrigated arable land and land under permanent crops	607	14,925		1,274	
	Per cent				
Arable land and land under permanent crops as percentage of total area	9.25	19.21	30.65	4.83	37.55
Permanent meadow and pasture as percentage of total area	73.08	27.81	49.61	58.37	24.60

- Sources:** (1) Bureau of Statistics. Report on agricultural and pastoral production for 1959/60. (Agricultural Census Report).
- (2) Production Yearbook, 1967 (Vol. 21) Food and Agriculture Organisation of the United Nations, Rome. pp. 3-10.

* In 1971 South Africa will convert all weights and measures to the Metric System. Areas will be expressed in hectares and not in morgen as in the past.

1 hectare = 1.167499 morgen. 1 morgen = 2.11653 acres.

Yields per unit on South African arable land are low compared with the important agricultural countries of the world as illustrated for maize and wheat in Table 2.2.

TABLE 2.2. YIELD PER HECTARE FOR MAIZE, WHEAT AND SUGAR CANE

	<u>1948-52</u>	<u>1952-56</u>	<u>1962-66</u>
<u>Maize:</u>	Yield in 200 lb bags per hectare		
South Africa (European farms)	9.0	10.9	13.5
United States	27.4	29.2	47.3
Latin America	11.9	11.8	13.7
Europe	13.7	17.0	27.2
World total	17.5	18.7	24.4
<u>Wheat:</u>	Yield in 200 lb bags per hectare		
South Africa (European farms)	6.7	7.6	7.2
United States	12.4	13.8	19.1
Europe	16.2	17.9	23.7
World total	10.9	11.9	13.9
<u>Sugar cane:</u>	Metric tons per hectare		
South Africa (European farms)	59.7	66.4	78.3
Cuba	42.5	46.7	48.5
World total	41.9	58.2	31.1

Source: (1) Production Yearbook, 1967 (Vol. 21) Food and Agriculture Organisation of the United Nations, Rome.
 (2) Supplementary data to the abstract of agricultural statistics of the Republic of South Africa. Division of Agricultural Marketing Research. (1 metric ton = 2,204 lbs)

The per unit yield for maize in the United States during the period 1962-1966 was about four times as high as the South African figure. This commodity is next to wool, the most important export product of South Africa.

The beneficial effects of technological advantages are also shown in Table 2.2. The per unit yield of maize and wheat for all countries increased substantially during the period considered.

South Africa has a comparative advantage with respect to sugar cane. The production of this crop is however only confined to the coastal region of Natal, and to the Lowveld of the Transvaal.

Maize, wheat and sugar cane are the three most important field crops in terms of gross value.

The output per labour unit in wheat and maize production is expected to be much higher in the United States than in South Africa largely because agricultural industries are more mechanised in the States.

Much of the natural vegetation in South Africa affords poor grazing largely due to the highly seasonal and erratic rainfall (122, p. 2).

TABLE 2.3. CATTLE PRODUCTS, 1965/66.

Country	Cattle numbers (1000's)	Production of beef and veal (1000 metric tons)	Butter (1000 metric tons)	Cheese (1000 metric tons)
South Africa (European and native)	12,500	400	41	14
New Zealand	7,218	292	258	107
Australia	17,936	882	209	60

Source: Production Yearbook, 1967. (Vol. 21). Food and Agriculture Organisation of the United Nations, Rome.

TABLE 2.4. SHEEP PRODUCTS, 1965/66.

Country	No. of sheep (1000's)	No. of sheep and lambs ^{**} slaughtered (1000's)	Production of wool (1000 metric tons)
South Africa (European and native)	42,102	8,300 [*]	136
New Zealand	57,343	17,894	322
Australia	157,563	24,933	798

* Figure refers to 1967. ** 1 sheep = 2 lambs

Source: Production Yearbook, 1967. (Vol. 21). Food and Agriculture Organisation of the United Nations, Rome.

Tables 2.3 and 2.4 compare the productivity of South African sheep and cattle with those of New Zealand and Australia.

New Zealand with a third more sheep than South Africa produces more than double the amount of mutton and wool. Australia with 50% more cattle than South Africa produces more than double the amount of beef and veal, butter and cheese.

Despite the natural disadvantages of the agricultural industry of South Africa one of the major problems that the industry faces is that of chronic surpluses.

It was deemed necessary to present a closer look at the importance of forage crops due to the close integration of the animal factor in the farming system in South Africa. In the following table it is seen that forage crops are almost of equal importance in Natal, the Transvaal and the Orange Free State.

TABLE 2.5. LUCERNE, LEY AND FODDER CROPS AND ENSILAGE 1961/62. (BANTU RESERVES INCLUSIVE)

Province	Lucerne	Perennial ley crops		Annual fodder crops	Total area (lucerne, perennial & annual crops	Area under artificial pasture as percentage of all land	Ensilage
		Pure grass pastures	Mixed grass & legume pastures				
	Hectares					%	Metric tons
Cape	203,469	24,705	24,715	35,417	288,306	.50	469,410
Natal	3,041	16,225	13,338	12,199	44,803	.95	315,284
Transvaal	16,337	66,099	11,450	74,522	168,408	1.06	460,134
Free State	29,815	49,942	5,791	64,400	149,948	1.28	350,842
South Africa	252,662	156,971	55,294	186,537	651,465	.73	1,595,670

Source: Bureau of Statistics. Report on agricultural and pastoral production for 1961/62. (Agricultural Census Report).

According to the 1959/60 agricultural census, a major portion of cultivated land was devoted to perennial pastures (other than lucerne) only in the E2 and E4 agro-economic regions,* Diversified Farming Regions East of the Drakensberg mountains. Dairying and the sale of cattle supplemented by sheep are the main sources of income from these areas. Only about .2% of the total land area in the country is taken up by perennial ley crops.

* The agro-economic classification is discussed in Section 2.3.

From Table 2.5. it may be concluded that livestock in this country is still raised on an extensive basis. The shortage of satisfactory fodder crops according to the annual report of Agricultural Technical Services (1965/66) can be ascribed to the following reasons (28):

- "(1) The greatest need thus far has been to find crops for conditions which are unsuitable for most other crops.
- (2) In most regions existing fodder crops cannot compete financially with cash crops.
- (3) Fertilizing of fodder crops, especially of grasses, is still expensive."

The winter cereals, barley, oats and rye, are extensively used as livestock feeds. In the winter rainfall area these cereals are grown as grain crops, in the summer rainfall region they are cultivated for green winter feed. Generally only about one-third of these cereals is marketed, the rest being retained on farms (82, p.82).

2.2. The output mix

In the period 1963-1967 livestock contributed about 44% of the gross value of agricultural production. Livestock has always been an important earner of income for the agricultural sector according to Table 2.6. During the last decade it appears, according to Table 2.6., that field crops have gained in importance over livestock products.

The most important agricultural products are shown in Table 2.7.

TABLE 2.6. GROSS VALUE OF AGRICULTURAL PRODUCTION FOR SOUTH AFRICA, AVERAGES IN FIVE-YEAR PERIODS, 1923-27 TO 1963-67 (BANTU RESERVES INCLUDED)

Period	Field Crops		Horticultural products		Livestock products		Total	
	Rm	%	Rm	%	Rm	%	Rm	%
1923-27	40	36	12	11	58	53	110	100
1928-32	36	34	14	14	53	52	103	100
1933-37	39	37	17	15	50	48	106	100
1938-42	55	37	23	16	71	47	149	100
1943-47	91	36	45	17	122	47	258	100
1948-52	164	35	66	14	239	51	469	100
1953-57	269	38	95	13	349	49	713	100
1958-62	317	40	117	15	359	45	793	100
1963-67	420	40	168	16	457	44	1045	100

- Source: (1) Union Statistics for 50 years. Jubilee issue 1910-1950. Bureau of Census and Statistics.
- (2) Supplementary data to the abstract of Agricultural Statistics of the Republic of South Africa. Division of Agricultural Marketing Research, 1969.

TABLE 2.7. IMPORTANT AGRICULTURAL PRODUCTS IN SOUTH AFRICA DURING THE FIVE-YEAR PERIOD 1963 TO 1967. (BANTU RESERVES INCLUDED).

Product	Average value of gross output	Gross output as % of total agricultural production
	Rm	%
Maize	205	19.6
Cattle slaughtered	114	10.9
Fresh milk and dairy products	109	10.5
Fruit including vine products	107	10.3
Wool	100	9.6

Source: Supplementary data, Division of Agricultural Marketing Research, 1969.

About 40% of the total area tilled is sown to maize according to the agricultural census of 1963. This is the most important crop in terms of gross value and it constitutes the staple diet of a large proportion of the population. Climatic conditions have led to great variations in the production of this crop from year to year. The maize production on European farms increased from 26 m. bags for the period from 1948 to 1952 to 63 m. bags for the period from 1963 to 1967.

Unlike maize, the greater part of which is locally consumed, wool has always been an export commodity. With an average value of exports of R114 m.* during 1963 - 1967, wool is by far the most important agricultural export product. Some 80% of the woolled sheep owned by Europeans are Merinos, but slaughter sheep are also an important source of income to the sheep farmer.

Cattle farming, like sheep farming, has two important branches; dairy farming and beef production. Both of these are primarily for the local market.

Maize, sheep and beef farming are the three most important branches of farming. South African agriculture is diversified and a great variety of other products are grown. In the livestock class, the gross value of poultry products increased from R36 m. in 1962-63 to R64 m. in 1967-68, to become one of the important livestock products. Horticultural products include deciduous fruit, citrus fruit, viticulture and vegetables, and fruit, including vine products, contributes 10% of the gross output of agricultural production. Amongst the deciduous fruit trees of bearing age, peaches (42%), apricots (29%) and apples (17%) are numerically dominant, but, in terms of exports,

* This includes all wool exported from South African ports. A part of the wool clip is also exported in a processed form. This explains why the gross production figure is less than the export figure.

apples and pears are the most important. More than 80% of the citrus trees are oranges (82, pp. 91-95). The other important field crops are wheat and sugar cane. In 1935 Leppan (95, p. 9) stated that for those enterprises in which South Africa enjoys a comparative advantage are also those whose surplus output is most likely to be in demand abroad, namely, animal and horticultural products.

The following products are classified by van der Merwe (141, p. 8) as regular and predominantly export products: fruit, wool and mohair, karekul pelts, hides and skins and wattle extract. He also classified the following products as regular to fairly regular export products: sugar, oilseeds and oil, maize, grain, sorghum, and sultanas and raisins.

Exports of agriculture and mining pay in full for all imports of equipment and materials used by the various sectors. With a proportionate decline in the mining sector it can be expected that the country will be made more dependent on materials locally produced, making the agricultural sector more important (7, p. 26).

2.3. Agro-economic classification of land

Agricultural economic research, undertaken by qualified economists, began in South Africa in 1925 with the inception of the Division of Economics and Markets of the Department of Agriculture (5, pp. 17-23). These studies are of a micro-economic nature and throw light on the farming structure in the various areas. The need for the identification of homogeneous agricultural areas arose as a result of these first surveys.

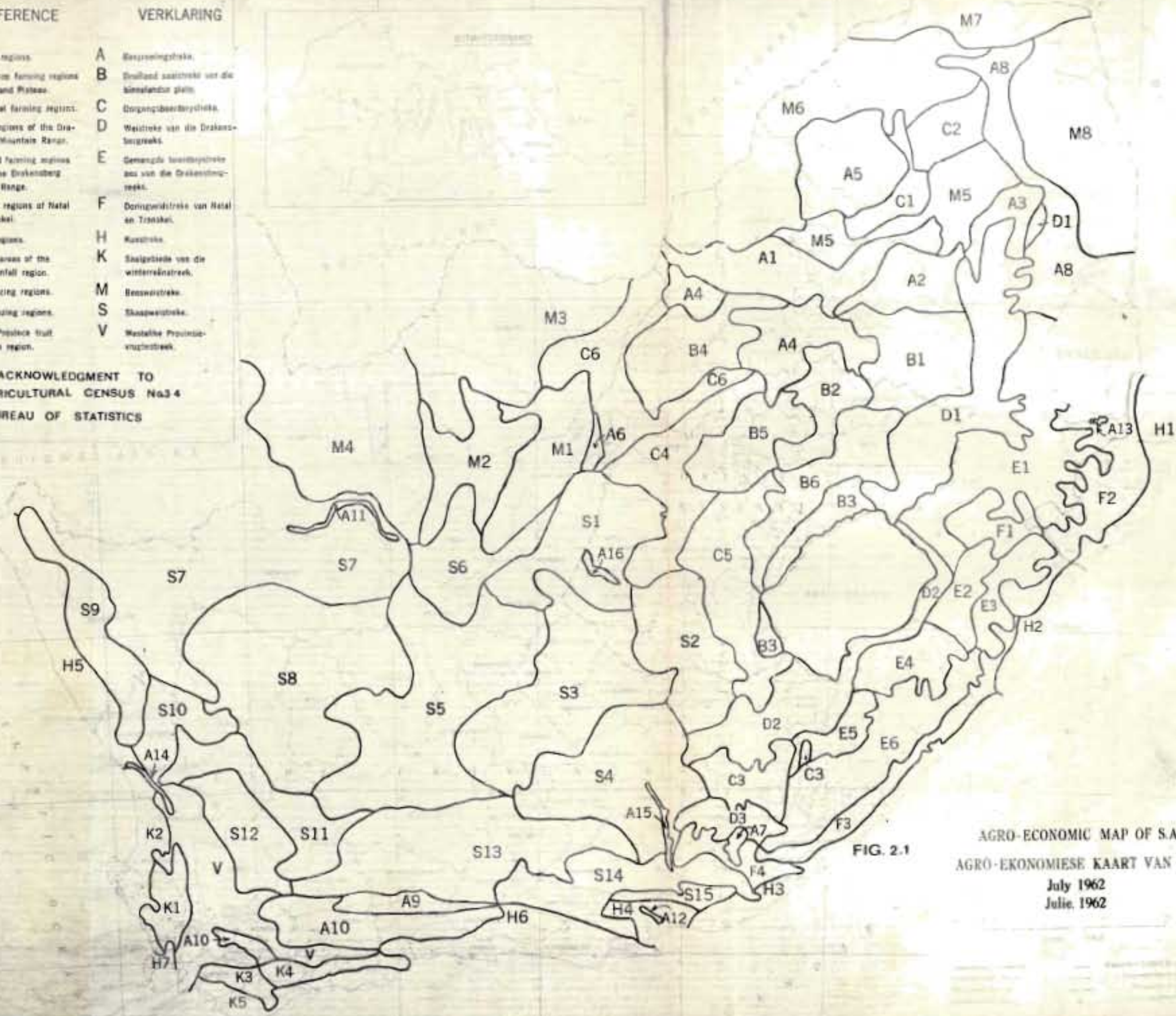
The agro-economic difference in South Africa can best be described by the agro-economic map as portrayed in Fig. 2.1. This map

REFERENCE

VERKLARING

- | | | |
|---|---|--|
| Irrigation regions. | A | Bevoeringingsreëls. |
| Dryland crop farming regions of the inland plateau. | B | Grondland saaiende van die binnelandse vlakke. |
| Transitional farming regions. | C | Oorgangsbeveerdersreëls. |
| Grazing regions of the Drakensberg Mountain Range. | D | Wesreëls van die Drakensbergreëls. |
| Diversified farming regions east of the Drakensberg Mountain Range. | E | Gemengde landbouereëls oos van die Drakensbergreëls. |
| Thornveld regions of Natal and Transkei. | F | Doringveldomreëls van Natal en Transkei. |
| Coastal regions. | H | Kusstreke. |
| Cropping areas of the winter rainfall region. | K | Saaigebiede van die winterreënstreek. |
| Cattle grazing regions. | M | Beesweidreëls. |
| Sheep grazing regions. | S | Skaapweidreëls. |
| Western Province fruit production region. | V | Weslike Provinsie vrugteproduksie reëls. |

WITH ACKNOWLEDGMENT TO
AGRICULTURAL CENSUS No 34
BUREAU OF STATISTICS



AGRO-ECONOMIC MAP OF S.A.
AGRO-EKONOMIESE KAART VAN S.A.
July 1962
Julie 1962

is based on agro-economic surveys undertaken by the Division of Economics and Markets. The purpose of these surveys was to divide the country into its more important agricultural regions. "Such a region should be reasonably homogeneous (of the same character) with regard to its most important physical, climatic and economic factors which are the decisive factors in giving a region its own character regarding the farming systems in practice." (22, p. 9). The boundary between agro-economic regions is established where the influence of one or more controlling factors increases or decreases sharply and from this a change in the nature of the region and farming system results. With a gradual increase or decrease of controlling factors, for example, rainfall, the boundary can only be established with a certain amount of variation.

South Africa is divided into eleven main regions which are further sub-divided into 87 sub-regions.

Because of the importance of this classification on inter-regional resource allocation, the main regions will be briefly discussed.

Irrigation regions (A). Irrigation, in whatever form, plays a decisive rôle here. The A region is divided into 16 sub-areas. In 9 out of the 16 sub-areas Government Irrigation Schemes predominate (138, p. 30). Farming in these areas falls either completely or partially under the control of the Department of Lands, but in the remaining seven areas it is chiefly in the hands of individual farmers. An economic unit in this area has been estimated at 26 hectares of irrigable land (138, p. 30). The soils of this area vary to such an extent that no general description is possible (22, p. 10).

Dryland crop farming regions of the inland Plateau (B). This area is often called the Highveld Area and is also known as the Maize Triangle. The area is situated on a plateau of 1,500 metres above sea-level in the east which drops in the west to nearly 900 metres. It falls in the summer rainfall area and the precipitation declines from approximately 66 cm. in the east to 50 cm. in the west (138, p. 31). Very little opportunity for irrigation exists in this area. The soil varies from sand to sandy loam and in heavier areas sandy clay loam predominates (22, p. 11). The average farm size is estimated to range from 340 to 430 hectares (138, p. 31).

Transitional farming areas (C). These areas fall between areas where field-husbandry is the main source of income and areas where stock-farming predominates. With a rainfall between 48 and 56 cm., crop production is uncertain. Since these regions are scattered, conditions vary considerably.

Grazing regions of the Drakensberg Mountain Range (D). This is a mountainous area with little arable land. (In general only fodder crops are cultivated). Since this is a grassveld area cattle is important in the mixed farming systems.

Diversified farming regions east of the Drakensberg (E). This area consists of mountainous or broken veld, and rivers originating in the mountains have carved out deep valleys. The rainfall varies between 64 and 89 cm. The greater part is sourveld with a high carrying capacity in summer, but poor grazing in winter. Cattle are the main source of income, supplemented by sheep. Crop farming is undertaken only in some parts.



Thornveld regions (F). This is a tall-grass area with sweetgrass predominating and thus suited for cattle farming. With a rainfall of from 50 to 60 cm. crop farming is possible to some extent. Sixty-three per cent of the total area consists of Bantu territory.

Coastal regions (H). This area lies along the coast from Mocambique up to the border of South-West Africa. The sub-areas H1, H2 and H3 fall in the summer-rainfall area and have a relatively high rainfall. H5 and H7 fall in the winter rainfall area and the remaining areas lie in the transition area of summer and winter-rainfall. The H5 sub-area has a precipitation of less than 13 cm. and has virtually no agricultural significance. On the basis of the 1959/60 agricultural census, 50% of the farming area in the H2 region is cultivated with sugar cane.

Cropping areas of the winter-rainfall region (K). Since these areas fall in the winter-rainfall area, winter cereals (wheat, barley, oats and rye) play an important rôle in the farming systems. The Swartland (K1) and Rens (K3) have diversified farming systems with the animal factor closely integrated with the growing of small grains. The remaining areas are more suited to livestock than to crop farming. The dominant soil type in the K region is the shallow, gritty, sandy loam to sandy clay loam which rests on clay.

Cattle grazing regions (M). These are bushveld areas and grazing consists mainly of sweetveld and edible shrubs and trees. Due to low and uncertain rainfall the veld has a low carrying capacity. The carrying capacity varies between 17 hectares (M4) and 7 hectares (M6) per animal unit with 9 hectares as the average.

Sheep grazing regions (S). The S region is by far the largest region and covers approximately 40% of the total area of the Republic, the main portion receiving an annual rainfall of less than 25 cm. The S2 and S15 sub-areas with a rainfall of more than 40 cm. do not really fit in with the rest of the region. Considerable differences in the carrying capacity of the veld exists as the rainfall varies greatly between sub-areas. As the result of this the head of sheep per 100 morgen (86 hectares) has been calculated for the S12, S3 and S15 regions as 18, 48 and 96 respectively.

Western Province fruit production region (V). This is a mountainous region. The rainfall in the mountains is high and orchards have been established in every valley and kloof. The kind of fruit varies between sub-areas. Certain areas are more suited to grapes, others to apples, pears and peaches. Farm income is supplemented by wheat, vegetables, cattle and Merino sheep. Turkish tobacco is also grown.

The resource use between agro-economic areas differs considerably and it was felt appropriate to point out these differences. In Table 2.8 the resource use per farm is shown for the various regions. This information is derived from data presented on a magisterial district basis in the 1959/60 agricultural census (see Appendix B.). Magisterial districts were aggregated into agro-economic regions using the map presented in Fig. 2.1. The data presented can be considered to be more reliable for the main regions because of the difficulty in classifying the small regions into magisterial districts.

Data on salaries and wages and depreciation of capital items are given in the 1959/60 census in the form required for the various agro-economic sub-regions. These data were consequently used and

TABLE 2.8. RESOURCE USE PER FARM FOR EACH OF THE AGRO-ECONOMIC REGIONS.*
(EXCLUDING RESERVES)

Regions	Gross income from livestock as percentage of total gross income	Current expenditure	Capital depreciation plus 6% interest	Salaries and wages (Whites and non-Whites)	Land value (5% of total value)	Gross value of production
	%	R				
A	47.3	1,744	360	1,096	1,236	5,682
B	40.6	3,230	639	1,091	1,537	9,106
C	59.4	2,260	509	835	1,420	6,478
D	71.4	2,852	422	782	1,524	6,840
E	61.4	2,135	454	1,404	1,967	7,317
F	68.2	1,972	431	1,477	1,800	7,710
H	50.1	1,799	407	2,042	1,344	6,549
K	39.6	3,865	896	1,242	1,871	10,642
M	50.8	1,837	354	773	1,643	5,706
S	88.8	2,604	457	886	2,314	6,953

* Information on the V-region is not presented because only a few magisterial districts are covered by this region.

- - - - -

presented in Table 2.8.

It is also important to note that data for the Transkeian territories and Zululand were not included largely because of the relatively high ratio of Bantu to White holders for these areas, and the general unreliability of the data from the Bantu areas.

According to Table 2.8 livestock made an important contribution to gross income in all the areas. What is striking from this table is the similarity in resource use per farm for the various regions. In

the majority of the regions the gross income per farm varied between R6,000 and R8,000. A clearer picture of regional differences can be obtained when resources per unit of land are compared, as shown in Table 2.9. The H-region with the most intensive factor use per hectare also showed the greatest gross value per hectare. The S region with the lowest factor cost per unit of land, also had the lowest gross income per hectare. As can be expected the extensive regions (A, B, H and K) showed the highest cost per unit. When the A, B, H and K regions are compared then it is interesting to note that labour

TABLE 2.9. RESOURCE USE PER HECTARE FOR EACH OF THE AGRO-ECONOMIC REGIONS (EXCLUDING RESERVES)

Regions	Current expenditure	Capital depreciation plus 6% interest	Salaries and wages (Whites and non-Whites)	Land value (5% of total value)	Gross value
	R per hectare				
A	5.43	1.05	3.46	4.32	17.68
B	7.51	1.48	2.52	3.57	21.17
C	4.49	.86	1.44	2.83	12.89
D	3.82	.54	.99	2.04	9.14
E	3.08	.69	2.15	2.84	10.55
F	3.48	.86	2.94	3.18	13.85
H	6.85	1.14	5.72	5.11	24.93
K	6.89	1.40	2.21	3.34	18.97
M	1.69	.19	.41	1.52	5.25
S	.93	.16	.30	.83	2.49

cost per unit of land is relatively higher in the A and H regions while the capital cost per unit of land is lower for these two regions indicating some kind of substitution between labour and capital. On the average the resources appear to be complementary, the resource costs of all resources are high for certain resources and low for others.

2.4. Economic interference in the resource and product markets. Two main types of interference may be identified here: (a) subsidisation of resources, and (b) restrictions on the movement of farm labour. The establishing of product prices above the free market equilibrium also has a very important effect on the demand for resources.

2.4.1. Price interference in the resource market.

A substantial amount is spent annually on subsidies and rebates as shown by Table 2.10. The total subsidies and rebates on resources have increased gradually from R1.6 m. for 1948-50 up to R17.8 m. for 1968. Subsidies on products increased during the same period from R14.3 m. to R54.7 m. Both types of subsidies, viz. production and resource subsidies, have an important effect on the optimum allocation of resources. There is, however, one broad difference between these two measures. Subsidies on a particular resource should increase the optimum use of this resource for all products while subsidies or price supports for a particular product should increase the optimum use of all resources for that product.

The resource subsidies may be divided into subsidies on fertilizer and subsidies on feed.

2.4.1.1. Fertilizer subsidies.

From Table 2.10 it can be seen that since 1960 the Department has favoured direct subsidies rather than

TABLE 2.10.

SUBSIDIES AND REBATES BY THE DEPARTMENT OF AGRICULTURAL ECONOMICS AND MARKETING

Year ended 31 March	Wheat (bread)	Maize (mainly distribution margin)	(1) Kaffircorn	Dairy products (mainly butter)	Total subsidy on products	Rebate on transport of:			Subsidy on fertilizer	Subsidy on stock feed and grazing	Total subsidy on resources	Total subsidy (products and resources)
						Stock feed	Live- stock	Ferti- lizer				
					R1,000							
1948-50	7,948	4,939	-	1,369	14,256	-	1	610	1,027	-	1,638	15,894
1951-53	15,489	8,475	-	2,547	26,511	12	11	725	1,353	-	2,101	28,612
1954-56	14,892	11,605	-	2,593	29,090	13	12	1,332	1,683	-	3,040	32,130
1957-59	14,327	9,355	-	2,584	26,266	24	12	2,691	2,042	-	4,767	31,033
1960	13,018	9,003	-	2,566	24,587	62	26	3,442	2,365	-	5,895	30,482
1961	12,805	8,800	-	2,968	24,573	182	54	3,598	2,371	-	6,205	30,778
1962	10,570	12,014	-	3,559	26,143	53	170	3,631	2,695	-	6,549	32,692
1963	13,133	14,298	-	4,423	31,854	305	161	3,881	2,967	-	7,314	39,168
1964	12,468	14,356	-	4,608	31,432	80	195	4,996	3,202	-	8,473	39,905
1965	13,612	14,425	-	4,534	32,571	422	83	3,834	4,230	656	8,569	41,140
1966	17,147	15,810	223	4,599	37,779	806	129	946	7,950	3,148	12,979	50,758
1967	20,065	25,346	638	4,477	50,526	1,919	668	948	7,908	4,972	16,412	66,938
1968	25,800	23,600	600	4,700	54,700	n.a.	2,200	n.a.	14,400	1,200	17,800	72,500

Source: Annual Report of the Secretary for Agricultural Economics and Marketing for the period 1st July, 1966 to 30th June, 1967.

(1) Rebate on transport is included. n.a. not available. - no subsidy.

transport subsidies. This in itself should have had an interfarm or interregional allocative effect with the farms or regions closer to the distribution centres of fertilizer benefitting at the cost of those further away. During the 1966-67 production year a transport rebate of 83 cents per metric ton on agricultural lime and magnesite, with a maximum of R2.20 per metric ton and a rebate of 55 cents per metric ton on compost, kraal manure and fowl manure with a maximum of R1.10 per ton were paid out (24). Transport rebates on high grade fertilizers to farmers were discontinued in 1965 (24).

During 1967 direct payments on fertilizer were established at R22, R50 and R9 per metric ton respectively for pure nitrogen, citric acid-soluble phosphate and potassium.

Fertilizer subsidies in 1967 amounted to 80% of the subsidies on resources and 20% of total subsidy. With a total expenditure on fertilizer of approximately R55 m., a subsidy of R14 m. should have an important allocative effect.

2.4.1.2. Food and livestock subsidies.

Transport subsidies on livestock are paid out on the transport of livestock to and from drought stricken areas. These payments are, therefore, considered as resource subsidies, payments to the factor of production, livestock. A rebate of 75% on the transport of stock to and from pasturage distress areas and on the transport of stock feed to such areas was paid during 1966-67 (24). The same rebates also applied to private transport in the case of certain areas. These rebates are adjusted from time to time.

A fodder subsidy scheme was instituted during 1964 in order to maintain nucleus breeding herds in drought stricken areas. The

subsidy on stock feed is limited to R1.25 per month per head of cattle for not more than 400 head of breeding cattle. In the recognized sheep regions, the subsidy on ewes is limited to 20 cents per ewe per month, for not more than 1,000 ewes.

2.4.1.3. Loan schemes.

The granting of loans at reduced rates is another form of price interference in the resource market.

Prior to the establishment of the Department of Agricultural Credit and Land Tenure, credit facilities for farming purposes were provided by the State through various Government institutions such as the Department of Lands, Water Affairs, Agricultural Technical Services, and the Farmers' Assistance Board (23). With the passing of the Agricultural Credit Act of 1966 (Act No. 28), measures to assist farmers financially were co-ordinated in one Department. Different types of loans are also available to farmers via the Land Bank. The purposes of the various loans granted are twofold:-

- (a) Financial assistance given by the State for the promotion of particular agricultural developments considered to be of national importance, viz. land settlement schemes, water and soil conservation.
- (b) Government loans granted in the form of distress relief when setbacks of a local or nation-wide nature are experienced in the agricultural sector (139).

The Central Government loan expenditures on votes for agricultural departments increased from an average of R4.4 m. for the five year period 1948-1952, to an average of R15.8 m. for the five year period 1963-1967 (10). The total indebtedness of agriculture

is estimated at R1,031 m. for 1967. This amount was supplied by the Land Bank, 18%, commercial banks, 22%, co-operatives, 6%, government, 11%, insurance companies, private persons and other institutions, 43% (29).

2.4.1.4. Assistance under the Soil Conservation Act.

According to the legislative power of the Soil Conservation Act No. 45 of 1946, the owner of land no longer has the right to abuse or destroy land. A National Soil Conservation Board was set up under the Act in order to improve farming methods in co-operation with farmers. The Act also provided for the proclamation of soil conservation areas. In the proclaimed areas considerable powers were granted for the regulation and prohibition of certain practices. By June 1958, 90% of the farm land in the country, excluding land reserved for Bantu, was proclaimed as soil conservation areas (81, p. 61).

Great progress has been made since 1946 in the sense of increased productivity. The number of sheep increased by 26% between 1946 and 1968 but the physical output of wool increased by 39% and sheep slaughtered by 57%. Cattle numbers declined over the same period but dairy products increased by 138% and slaughtered stock increased by 43% (81, pp. 230, 231) (31).

Since 1946 various acts have been passed to strengthen and amend the Conservation Act of 1946 (114). The soil conservation laws were consolidated and amended in 1969 and made applicable to all land not situated in urban areas and of which the ownership is not in terms of the Bantu Trust and Land Act, 1936 and the Rural Coloured Areas Act, 1963 (114).

The objects of this Act are to combat and prevent soil erosion and for the conservation and improvement of the soil, the vegetation and the sources and resources of water supplies.

Under the Act the Minister of Agricultural Technical Services may order owners of land to carry out certain conservation works at the owner's expense.

The Minister may establish a soil conservation committee in any district to advise him and the owners of land on matters relating to soil conservation. If conservation works of an owner of land increase the value of land belonging to another person, then the latter person may be ordered to pay the former an amount equal to the amount by which the value of his land has increased.

Subsidies and grants may be paid for conservation works subject to conditions determined by the Minister. The costs of conservation works may be charged entirely to the State or entirely to the owner of land, or partly to the State and partly to owners of land.

2.4.1.5. Indirect assistance through government departments other than the Department of Agricultural Economics and Marketing.

The Central Government revenue expenditure on votes for the Departments of Agricultural Technical Services and Lands respectively increased from an average of R7.9 m and R1.3 m for the five year period 1948-1952 to an average of R21.7 m and R1.8 m for the five year period 1963-1967 (10, p. 155). The expenditures of the Department of Agricultural Technical Services consist mainly of salaries and wages of departmental employees, and of expenditures on various research institutes, agricultural training and education, and of soil conservation (28). Expenditures under the

vote of the Department of Lands, before its conversion into the Department of Agricultural Credit and Land Tenure, consisted mainly of administrative expenditures, but also included maintenance of State lands and of State irrigation settlements and works (10, p. 154). The Department of Water Affairs also pays out large amounts annually on the construction of dams which are also being utilized for non-farming purposes.

2.4.2. Interference in the product markets.

2.4.2.1. Schemes under the Marketing Act.

The Marketing Act which was adopted by Parliament in 1937 provided for the introduction of marketing schemes for farm products by proclamation instead of specific parliamentary enactment for each product.

The principal objects of the Act are "firstly, to secure a greater measure of stability in the prices of farm products, and, secondly, to reduce the price spread between the producer and consumer." (113).

The following are some of the more important powers which may be granted to boards by the Act:

- (a) Producers may be prohibited from selling the regulated products except through the Board concerned.
- (b) Maximum or minimum prices may be fixed for the products.
- (c) Boards may enter the market as buyers or sellers of products.
- (d) Boards may impose levies on products. (113, p. 3).

At the moment there are 20 boards operating under the Marketing Act (31). These boards control more than 70% of the gross value of agricultural production (24). Broadly speaking the existing schemes can be divided into the following types (24):-

- (a) One-channel fixed-price schemes. Such schemes apply to maize, industrial milk and winter cereals. The boards determine from time to time absolute prices payable to producers of these products.
- (b) One-channel pool schemes. These schemes apply to leaf tobacco, deciduous fruit, citrus, dried fruit, chicory, oil seeds, lucerne seed, rooibos tea, fresh milk and cream, and bananas. Producers obtain a pool or average price from the sale of their produce.
- (c) Surplus-removal (floor price) schemes for meat, potatoes, eggs, dry beans and kaffircorn. Producers of these products sell on the open market but the Control Boards concerned apply measures to support the market prices when necessary.
- (d) Supervisory scheme for canning peaches.
- (e) Sales promotion scheme for mohair.

The control boards impose levies on the products they control in order to cover their administration expenses (ordinary levy) and for the stabilisation of prices, sales promotion and research. The maize, dairy, tobacco and egg boards have had to draw heavily on occasions from their funds to meet the losses on exports. By expecting farmers to pay levies on the units of production (e.g., bags of maize) a tax is thus imposed on technology. This would result in a movement of the marginal cost (supply) curve to the left by an amount equal to the levy per unit of production. The supply curve is moved to the right by the introduction of new and improved technologies.

2.4.2.2. Subsidisation of products.

The payment of subsidies on the three staple foods, viz. bread, maize and butter increased to more than R54 m. in 1968 according to Table 2.10. These subsidies amount to approximately 24 cents per bag of white maize, $47\frac{1}{2}$ cents per bag of yellow maize, $1\frac{1}{4}$ cents per 2 lb loaf of bread and $4\frac{1}{2}$ cents per pound (.45 kg.) of butter (113, p. 32). These subsidies are payable on all local sales of

TABLE 2.11. RULING FARM PRICES OF VARIOUS FOODS CONVERTED TO SOUTH AFRICAN CURRENCY. 1964-1966.

Product	South Africa	U.S.A.	Australia	New Zealand	Argentina	Italy	Canada
	R						
Maize per bag (producer price)	3.01	3.10	-	-	2.34	4.80	-
Wheat per bag (producer price)	5.79	3.47	-	-	2.54	7.25	4.32
Beef cattle per 100 lb slaughter weight (wholesale price)	17.43	29.96*	17.53	14.83	15.50*	-	26.58*
Sheep & lambs per 100 lb slaughter weight (wholesale price)	23.10	33.03**	16.79	-	6.25**	-	-
Pigs per 100 lb slaughter weight (producer price)	17.77	18.70***	-	20.45	-	-	20.59

Source: F.A.O. Production Yearbook, 1967. Vol. 21.

* Slaughter weight considered to be 60% of live weight for beef cattle.

** Slaughter weight considered to be 52% of live weight for sheep.

*** Slaughter weight considered to be 74% of live weight for pigs.

these products. Initially the subsidies were introduced to absorb part of price increases from inflation but more recently with the advent of surpluses, the subsidies serve as a measure to support producer prices.

2.4.2.3. Product prices in South Africa compared with world prices.

In the previous table (Table 2.11) the prices of various products in South Africa are compared with prices realised in other countries. The Social and Economic Planning Council in their Report No. 4 concluded in 1944 that "If it were decided to adapt South African agricultural prices to world prices, very considerable reductions would be needed. At present the South African producer and wholesale prices are higher than those of the Argentine but compare favourably with prices in the U.S.A., Australia, New Zealand, Italy and Canada. It must, however, be borne in mind when these prices are compared that prices for various countries are not always given for the same grades.

The F.A.O. Yearbook for 1967 presents prices of maize for the U.S.A., Argentine, Italy, United Arab Republic, Yugoslavia, India, Mexico and the United Kingdom. Only in the Argentine was the price of maize lower than in South Africa.

The wheat price in South Africa is high in order to stimulate local production as the Republic is an importer of this commodity.

South African meat prices are also competitive when compared with prices of other countries.

It may be concluded that at present the farm prices in South Africa compare favourably with prices in the important producing countries.

Leppan (95, 3) rightly points out that where a protective

policy is followed as in South Africa the protection of grain crops may conflict with the stock-feeder in other parts of the country. This may encourage grain production in marginal areas like the Northern Transvaal, Southern Free State and North Western Cape. These areas have a highly erratic rainfall and it is doubtful whether it is in the interest of conservation to use these areas for crops. According to Leppan (95, p. 9) many areas in which grain growing is a hazardous undertaking, fodder production is suitable and can be used to stabilise pastoral enterprises.

2.4.3. The effects of economic interference on national welfare.

Reder states that under conditions of perfect competition all the marginal and second-order conditions of maximum welfare will be satisfied (112).

If by Government interference prices of resources and products are changed, then the first order conditions are not satisfied any longer and the welfare of society is reduced.

Under conditions of optimum production, producers will tend to equate marginal resource cost and marginal value product.

In the figure overleaf MC_1 and MVP_1 represent the marginal resource cost and marginal value product curves of an industry under perfect competition. Under optimum conditions the industry should employ OX_1 resources. When resources are subsidised, as is the case with fertilizer in South Africa, the marginal resource cost will be reduced as shown by the shift of MC_1 to MC_2 . This will encourage farmers to employ more of the subsidised resource.

When prices of products, through State interference, are fixed at levels above those that would prevail without interference, then

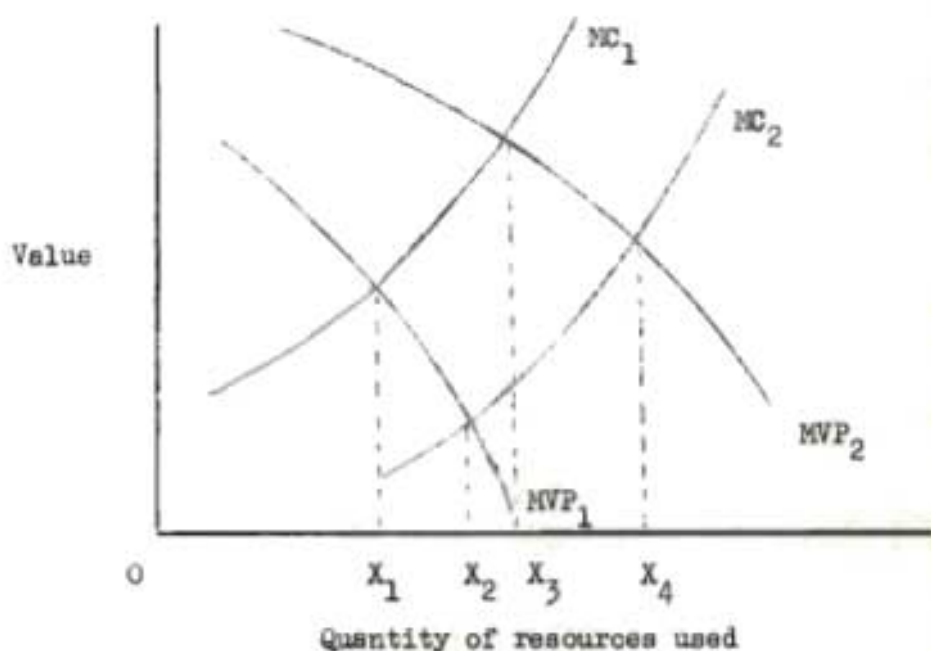


FIGURE 2.2. THE EFFECTS OF PRICE INTERFERENCE
IN THE RESOURCE MARKET.

the marginal value product is increased as indicated by a shift of this curve to the right. Farmers are thus given the incentive to produce more of this product and less of others.

Product price supports and subsidies of resources will tend to increase the resource use and production in the sectors favoured by interference. Under conditions of full employment this will result in resources being bid away from other industries.

Groenewald (60, pp. 283-293) shows that want-satisfaction would be reduced by government interference.

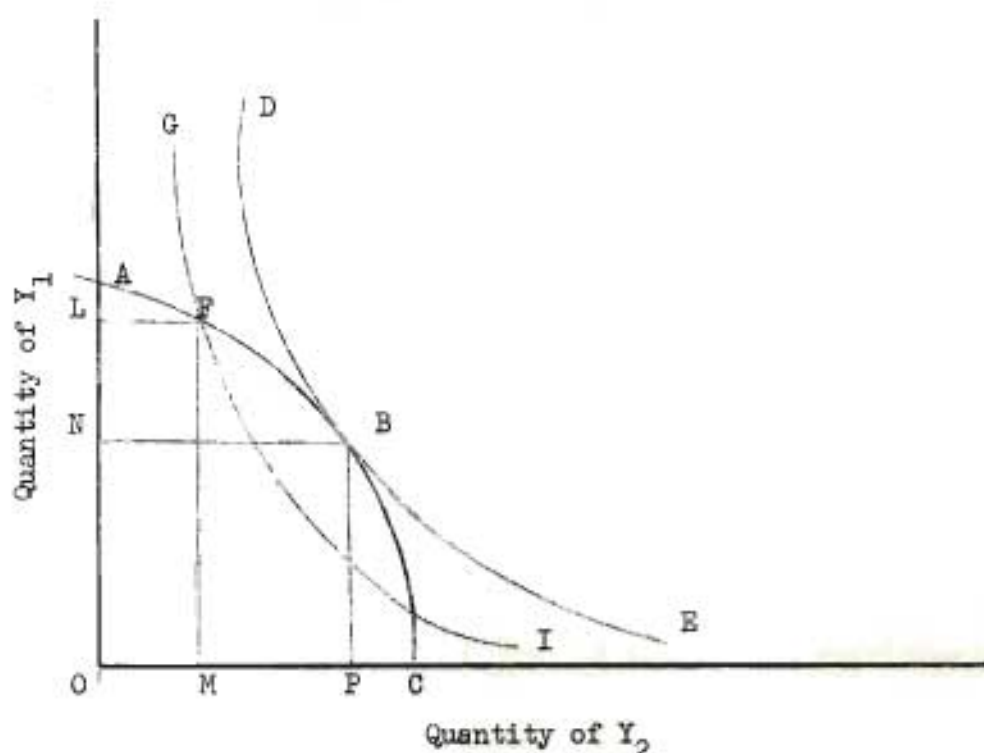


FIGURE 2.3. PRICE INTERFERENCE AND NATIONAL WELFARE.

Curve DBE is a community indifference curve and ABC a community production possibilities curve for two products Y_1 and Y_2 .

It is assumed here that when resources, a fixed level of technology, the pattern of consumers' preferences, full employment and mobility of resources are given, a maximum of want-satisfaction is aimed at.

The equilibrium between production and consumption will occur where the marginal rate of substitution of Y_1 for Y_2 in production is equal to the marginal rate of substitution of Y_1 for Y_2 in consumption.

Thus:

$$\frac{\delta Y_1}{\delta Y_2} \text{ (In production)} = \frac{P_{Y_2}}{P_{Y_1}} = \frac{\delta Y_1}{\delta Y_2} \text{ (In consumption)}$$

where P_{Y_1} and P_{Y_2} are the prices of products Y_1 and Y_2 .

Under these conditions welfare is maximised at point B where ON of Y_1 and OP of Y_2 are consumed and produced by the community.

With economic interference a reallocation of resources may occur and OL of Y_1 and OM of Y_2 may now be produced. The welfare of society is reduced as F lies on a lower indifference curve than B.

Wallace (143, pp. 580-594), using the premises that the area under the demand curve to the left of a given quantity represents total utility for that quantity and that the supply curve reflects opportunity costs of variable resources used to produce each quantity, showed that price support measures add more to the costs of society than to the total utility of the society. The net social loss for price support measures is shown to depend on the elasticity of demand and supply for the products under study.

All government interference is not necessarily to the disadvantage of society, for instance assistance under the Soil Conservation Act. The emphasis in this chapter is put on a description of the economic framework of agriculture and not on the criticism of it. To do justice to the latter, the various products affected must also be separately analysed.

2.4.4. Interference in the market for farm labour.

Legislation that inhibited the free movement of African farm labour existed as far back as 1927 through the Native Administration Act of 1927. The Urban Areas Act of 1945 consolidated various measures passed before then. "In general, the position in 1948 was that the individual African could move from one place to another only with official permission", according to Molteno, as quoted by Brookes (13).

Since then legislation has become very much more rigid and the Population Registration Act of 1950 requires that every African male over the age of 16 must carry an identity card with particulars of his identity. The identity card was incorporated with other documents* which Africans were required to carry under the Abolition of Passes and Consolidation of Documents Act of 1952, in one Registration Book which each African must carry at all times. This enables a strict control of African labour, urban as well as rural. This system is extended by the Labour Bureau System, establishing local and district labour offices which are directed by the Central Labour Bureau in Pretoria.

"A record of every registered African farm labourer is kept in a central register in Pretoria, and the position is that the labourer cannot be employed in the urban areas, because as soon as his service contract has to be registered it will be established that he is a farm labourer, and then he cannot legally be taken into service."**

The most important aims of these Labour Bureaux are to place workseekers in employment and to "regulate the supply and demand". (115). In order to pursue these aims and various other functions, every workseeker in a rural area must register himself with the district labour bureau of the Magisterial District in which he has been working. When he registers he is given a card which he produces to farmers when he is seeking employment. When a farmer employs such a workseeker he signs the worker's Reference Book to indicate that he is employed on that farm and may not be employed elsewhere until he has been discharged. Thus a close record is kept of each African farm labourer at each district labour bureau and at the Central Labour Bureau in Pretoria.

* Tax receipts, passes, service contracts, etc.

** Statement made by Mr. A. Vosloo, Deputy Minister of Bantu Development. Taken from "The Daily News", Saturday, October 11, 1969, p.9.

These Labour Bureaux, established by Government Notice No. 2495 of 1952 apply only to African farm workers and the regulations of the Bantu Affairs Department Bureaux do not apply to Coloured farm workers for instance. They are free to move between the rural and urban areas without restriction.

The migration of farm labour from the rural to the urban areas is regulated through the labour bureau system. The Urban Areas Act No. 25 of 1945 and the Influx Control regulation also make it impossible for an African farm labourer to seek employment in an urban area unless he has been granted special permission from his District Commissioner, who could refuse permission if, for example, there is a shortage of farm labour in the district. Therefore, if an African is registered as a farm labourer it is virtually impossible for him to obtain permission to do any other kind of work unless he is either qualified for permanent residence in an urban area, or the employment for which he is required in the urban area cannot be done by any African already in that area. It was the intention of the Urban Areas Act to halt the steady stream of African migration to the towns, as clearly set out under subsection (1) of section 10 of the Act, that only certain Bantu may be in a prescribed urban area for any period in excess of seventy-two hours (13, p. 109).

Through the legal verbiage of these regulations the following point emerges: that African farm labourers and their families can seldom, if ever, qualify for permanent residence in an urban area. An African farm labourer may however be requisitioned by the Regional Labour Bureau for employment in an urban area, but he must return to the rural area on termination of his employment.

It must be pointed out that migrant labour to the mines is exempt from the labour bureaux regulations. They may reside in the urban areas for the period of their contract, but they cannot establish permanent residence there.

Conclusively then, it is legal for African farm workers to move freely from farm to farm in the rural areas, provided they notify the labour bureaux concerned. They may also move from a European farming area to a Reserve, but they may not remain in an urban area for any purpose for longer than seventy-two hours. The employment and movement of African farm labour are thus strictly regulated by the existing laws.

Restrictions imposed on the movement of Bantu farm labour should have a similar effect in reducing maximum want-satisfaction as described in section 2.4.3. Furthermore, this should have a depressing effect on Bantu farm wages and it can be expected that the value of the marginal product of Bantu labour should be higher in industries than on farms. Economic forces may yet counteract the stated purposes of legislation.

Some of the effects of the immobility of the Bantu agricultural labour force can be illustrated as follows by taking a theoretical example from Heady (70, p. 159).

Let 2.1 be a one-factor production function for the agricultural industry where Q_p is the quantity produced, k_1 a constant term, b the elasticity of production and X the input of resources

$$Q_p = k_1 X^b \quad 2.1.$$

$$Q_d = k_2 P^{-e} \quad 2.2.$$

The product demand function is specified in 2.2. where Q_d is the

quantity demanded, P the price of the product, e the elasticity of demand and k_2 a constant.

Assume production increases to the proportion of a constant C_1 , times the original function and demand increases to a level of a constant C_2 , times the original function.

Using elementary calculus the marginal value productivity of the resource after the production and demand increases (MVP_2) can now be compared with the marginal value productivity of the resource before these shifts (MVP_1). The factor quantity is taken as constant.

$$MVP_2 = C_1^{(e-1)/e} C_2^{1/e} MVP_1 \quad 2.3.$$

This relationship can be shown more effectively by choosing different values for the parameters as in Table 2.12.

TABLE 2.12. MARGINAL RESOURCE PRODUCTIVITIES FOR SHIFTS IN PRODUCT DEMAND AND SUPPLY WITH RESOURCE INPUT CONSTANT.

Product price elasticity	Marginal value productivities	
	$C_1 = 1.5, C_2 = 1.5$	$C_1 = 1.5, C_2 = 1.2$
.1	1.5 MVP_1	.16 MVP_1
.4	1.5 MVP_1	.86 MVP_1
1	1.5 MVP_1	1.20 MVP_1

With the technological shift of the production function and the shift of the demand function being of the same magnitude ($C_1 = 1.5$, $C_2 = 1.5$), an increase in the productivity of labour can be expected. When the production increase is greater than the demand increase, the level of the new MVP of the resource depends on the elasticity of demand for the product. With production outstripping the demand in

South Africa and the free outmigration of Bantu labour restricted, the marginal value productivity of labour may increase very little or remain fairly constant. Restrictions placed on Bantu labour movement also leads to underemployment of this labour on farms. This factor coupled with the fact that labour supplies are unlimited in the Bantu homelands and other neighbouring territories not under South African control, has an important influence on the pattern of Bantu wages in South Africa. This statement will further be elaborated on when resource prices are discussed in section 3.3.

2.5. Tenure in South African Agriculture.*

In South Africa there are two different types of rural economies existing side by side; one is the essentially market-oriented farming, as practised by European farmers, and the other is the largely subsistence-oriented farming as practised by African peasants in the Reserves. Productivity on the European farms is in general several times greater than that on the African farms, both in output per acre and per unit of labour. Due to these marked differences the research in the thesis was restricted only to market-oriented farming which accounts for 87% of the total farming area in 1960 (16).

In South Africa and in the United States the majority of farms are owned (6). In the United Kingdom in 1966 there were some 220,000 full-time farms out of the total of 450,000 holdings and more than half the agricultural output is produced by 42,000 large farms (27, p. 4). The allodial form of tenure where the title to land is held in trust by the chief and each family is entitled to an allotment

* Professor H.I. Behrmann delivered his inaugural lecture on the "Technique and Tenure in South African Agriculture", May, 1965. Pietermaritzburg, University Press.

of arable land with grazing being communal, is almost universal in Bantu Reserves (6).

The percentage of owner-occupied farms increased gradually from 58% in 1918 to 80% in 1960. This has an important bearing on financing of the industry because if the owner-farmer is in need of money, he can obtain this by mortgaging his farm. In most cases owners are also working farmers. The other forms of tenure, viz. leased by occupier, occupied on share system and managed for other persons declined in importance from 1918 to 1960.

The passing of the European-held land into the hands of owner-occupiers is partly a reflection of the prosperous times through which farming has been passing (6).

The labour employed in agriculture consists of three main groups, (a) labour performed by the farmer and his family; (b) regular employees; and (c) casual or seasonal employees. Domestic servants sometimes also perform farm work.

In June 1960, 1,663,700 workers were in agriculture of whom 750,800 were regular employees and 591,900 were casual employees. Family labour also makes up an important part of the labour force. Non-Europeans were primarily employed as regular and casual employees and whites mainly as family labour.

In South Africa in 1960, 26.5% of the farmers had land set aside for Bantu which constituted 1.3% of the total area. The area set aside to labour tenants made up 50.3% of the total area set aside. The rest was set aside for full-time employees. Labour tenants which are mainly encountered in Northern Natal and the Northern Transvaal customarily work for 6 months for the farmer for a wage, but for the rest of the period they are free to work elsewhere. The tenant is

TABLE 2.13. NATURE OF TENURE OF EUROPEAN OCCUPIED FARMS

	1918		1925		1930		1937		1946		1955		1960	
	No. of farms	%	No. of farms	%	No. of farms	%	No. of farms	%	No. of farms	%	No. of farms	%	No. of farms	%
Owned by occupier	44,240	58.1	60,264	66.5	65,306	67.3	69,512	66.5	77,167	68.6	81,956	73.4	84,260	79.6
Leased by occupier	18,568	24.4	18,353	20.2	19,456	20.1	20,895	20.0	23,071	20.5	20,923	18.8	n.a.	n.a.
Occupied on share system	6,872	9.0	6,444	7.1	5,884	6.1	7,305	7.0	6,098	5.4	3,809	3.4	n.a.	n.a.
Managed for other persons	6,469	8.5	5,592	6.2	6,285	6.5	6,842	6.5	6,117	5.5	4,898	4.4	3,883	3.7
Total Number	76,149	100.0	90,653	100.0	96,940	100.0	104,554	100.0	112,453	100.0	111,586	100.0	n.a.	100.0

Source: (1) Social and Economic Planning Council, Report No. 4. The future of farming in South Africa. 1944. p. 7.

(2) Bureau of Statistics. Report on agricultural and pastoral production. Agricultural Census Report. Various years.

TABLE 2.14. LABOUR EMPLOYED IN AGRICULTURE (EXCLUDING RESERVES) JUNE, 1960.

	(in thousands)								
	Total	Whites		Bantu		Coloureds		Asiatics	
		Male	Female	Male	Female	Male	Female	Male	Female
Family labour	158.5	103.3	42.9	-	-	5.1	1.3	4.0	1.8
Managers	5.6	5.5	-	-	-	-	-	-	-
Regular employees	750.8	7.2	.5	542.7	94.9	89.7	9.4	5.3	1.0
Casual employees	591.9	1.2	.3	243.3	255.6	62.9	27.8	.5	.2
Domestic servants	156.9	-	.1	14.5	115.5	1.4	25.0	.2	.3
Total	1,663.7	117.2	43.8	800.5	466.0	159.1	63.5	10.0	3.3

Source: Bureau of Statistics. Report on agricultural and pastoral production. Agricultural Census No. 34. 1959/60.

neither a skilled farm labourer nor a farmer, nor does he ever become skilled in any other occupation (6).

Bantu on holdings of White farmers have 14% of the number of cattle, 18% of the pigs and 21% of the goats on the farms. They also plant 10% of the area devoted to maize on European farms (16).

CHAPTER 3.

TRENDS IN RESOURCE USE

Trends in the agricultural industry are a reflection of the pressures faced by farmers. Innovations alter the marginal physical rates of substitution in favour of the factors which experienced a relative increase in marginal productivity. This results in a change in the organisation of agriculture and in the factor mix. The optimum factor mix may continually change because of new technologies or of changes in relative resource prices.* If the marginal productivities of the resources are increased through innovations, the farmers' demand for inputs can increase even when product prices decline relatively to factor prices. This places a severe stress on the managerial ability of farmers.

3.1. Output per unit of input.

Increase in farm production can be attributed to increased productivity per unit of input and to the application of additional inputs. Productivity in the United States agricultural industry increased from an index of 100 in 1940 to 146 in 1960 (101, p. 4). Productivity is defined here as the ratio of total farm output to total production inputs for the U.S.A. With the same base period Groenewald (59, p. 23) estimated the productivity index for the South African agricultural industry to be 143 in 1959. Groenewald measured productivity as the ratio of physical yield per unit of primary production resource. Total production at constant prices increased by 78% from 1940 to 1959 in the

* The first order conditions specify that inputs should be used until the marginal rates of substitution between inputs are equal to the inverse of their respective price ratios.

Republic. From this it may be concluded that greater productivity contributed slightly more to output than an increase in resource use. Farm output increased by 51% in the U.S.A. from 1940 to 1960, suggesting that the increased output can almost solely be attributed to greater productivity. Increased productivity in South Africa resulting from the adoption of new technologies, usually lags a few years behind the U.S.A. consequently a parallel productivity increase cannot be expected.

During the same period total population, including that in Bantu Reserves, increased by 50% in South Africa and this demonstrates an increase in production per unit of population.

In Table 3.1 the ratios of output per unit of capital input and the capital input per unit of output, are shown. The following capital

TABLE 3.1. OUTPUT/CAPITAL INPUT RATIOS AND CAPITAL INPUT/OUTPUT RATIOS FOR SOUTH AFRICA, AVERAGES FOR FIVE YEAR PERIODS 1938-1967. (DATA NOT DEFLATED).

Year	Output per unit of capital input Percentage (1940 = 100)	Capital input per unit of output (R)
1940	100	4.64
1945	126	3.85
1950	150	3.22
1955	168	2.87
1960	164	2.96
1965	191	2.54

- Source:
- (1) Unpublished records of the Division of Agricultural Marketing Research. 1969.
 - (2) Supplementary data to the abstract of agricultural statistics. 1969.

assets were taken into account: fixed improvements, machinery, implements, motor vehicles and tractors, and the livestock inventory. The data in Table 3.1 were not presented on a deflated basis because of an inconsistency that was discovered between the volume of production and production at constant values as reported by the Department. Capital invested in land was excluded because greater productivity of the land may result in an increase in the land price. In such a case the output/capital input ratio is a very inefficient indication of productivity.

In Table 3.1, the gross value of agricultural production was taken as output. The output per unit of capital increased by 64% on an undeflated basis from 1940 to 1960. Since 1960 there appears to have been a substantial increase in the output per unit of capital input.

The assets required to produce one rand of gross output decreased from 1940, as shown by Table 3.1. In 1940, R4.84 of capital input was needed to produce R1 of gross output compared to R2.54 required in 1965 for the same output. This may be attributed to better varieties, improved pasture management, and the more intensive use of variable expenses such as fertilizers. Brand (10, pp. 145-147) reported capital/output ratios determined by Frenzen and Willers and du Plessis. According to these findings the capital/output ratios appear to be high in agriculture than in the mining or manufacturing sectors.

3.2. Resource substitution in Agriculture.

Non-purchased inputs such as family labour, farm manure, oxen, horses and mules, have been replaced by non-farm supplied inputs, such as machinery, fertilizer and hired labour.

The substitution between tractors and a span of 16 oxen is

depicted in Table 3.2. Tractors per farm in the North-West Free State increased from .7 in 1945/46 to 3.0 in 1956/57 while spans of oxen per farm decreased from 3.7 to .06.

The substitution placed a tremendous financial burden on the farmer. The introduction of such new technologies has magnified the problem of capital financing in farming.

TABLE 3.2. TRACTORS AND SPANS* OF OXEN PER FARM, NORTH-WEST FREE STATE AND TRANSVAAL HIGHVELD⁽¹⁾. 1945/1946-1966/1967.

Year	North-West Free State		Transvaal Highveld	
	Tractors per farm	Spans of oxen per farm	Tractors per farm	Spans of oxen per farm
45/46	0.7	3.7	.7	3.4
46/47	0.9	3.2		
47/48	1.2	2.8		
48/49	1.7	2.2		
49/50	1.8	1.2		
50/51	2.2	0.7	1.2	1.9
51/52	2.4	0.3		
52/53	2.3	0.2		
53/54	2.6	.03		
54/55	2.8	.08		
55/56	2.9	.10	1.9	.7
56/57	3.0	.06	1.9	.6
66/67 ⁽²⁾	4.7		4.3	

* 1 span = 16 oxen.

Source: (1) Gregory, J.J. (1962) Prys-en Inkomstebeleid in die landbou met spesiale verwysing na Suid Afrika. D.Sc. thesis, University of Pretoria, p. 96.

(2) Unpublished records of the Division of Agricultural Marketing Research.

TABLE 3.3. THE VALUE OF CAPITAL ASSETS IN AGRICULTURE, SOUTH AFRICA.
1935 - 1966.

Year (31 Dec.) Five year period with mid-year	Land		Fixed improve- ments		Machinery, implements, motor vehicles & tractors		Livestock inventory		Total	
	R =	%	R =	%	R =	%	R =	%	R =	%
1935*	332.2	40.3	209.5	25.4	53.8	6.5	228.7	27.8	824.2	100.
1940	378.8	34.4	351.7	31.9	72.8	6.6	298.3	27.1	1,101.6	100.
1945	769.4	43.7	454.0	25.8	107.4	6.1	430.8	24.4	1,761.6	100.
1950	1,390.7	48.0	640.6	22.1	305.3	10.5	561.8	19.4	2,898.4	100.
1955	2,040.9	49.9	789.4	19.3	470.5	11.5	789.2	19.3	4,090.0	100.
1960	2,472.0	51.3	932.6	19.4	510.8	10.6	902.0	18.7	4,817.4	100.
1965**	3,033.8	53.3	1,067.1	18.8	545.2	9.6	1,039.3	18.3	5,685.4	100.

Source: (1) Unpublished data of the Division of Agricultural Marketing Research.

(2) Supplementary data to the abstract of Agricultural Statistics, January, 1969.

* Based on period 1935 - 1937.

** Based on period 1964 - 1966.

In Table 3.3. the value of capital assets in agriculture is shown for the period 1935-1966. At present about 53% of all investment is in land, 19% in fixed improvements, 10% in machinery and 18% in livestock. The assets of land and machinery increased in relative importance over the period while that of fixed improvements and livestock decreased. The assets of land and machinery increased tenfold from 1935 to 1965 while that of fixed improvements and livestock increased fivefold.

Table 3.4 shows that while the share of both labour and capital in the total resource use remained relatively constant, both these resources substituted somewhat for land in South Africa. In the U.S.A.

the share of capital in the resource mix increased from 1870, while labour's share decreased (47, p. 167), demonstrating a substitution between these resources.

TABLE 3.4. CHANGES IN THE COMPOSITION OF RESOURCES IN THE SOUTH AFRICAN AGRICULTURE. RESOURCE PRICES BASED ON THE PERIOD 1947/1948 - 1949/1950 = 100.

Year	Percentage of total inputs			
	Labour	Land	Capital	Total
1929/30	20	16	64	100
1934/35	22	22	56	100
1939/40	22	18	60	100
1944/45	22	18	60	100
1949/50	28	13	59	100
1954/55	26	12	62	100
1959/60	22	11	67	100

Source: Gregory, J.J. 1962. Prys-en Inkostebeleid in die landbou met spesiale verwysing na Suid-Afrika. D.Sc. thesis, University of Pretoria, p. 167.

Expenditures on resources that are depleted during the course of one production season are only available from 1950. Expenditures on these resources have increased substantially since 1950-52 according to Table 3.5. Expenditures on fertilizers and farm feeds, dips and sprays more than trebled over the 15 year period. A part of the increase in expenditure can be attributed to higher factor prices. Fertilizers, feeds and repairs of machinery and implements are the most important current expenditure groups.

In order to measure the real changes of factor use, the growth

rates of the major inputs with 1949/50 as bases are depicted in Table 3.6

TABLE 3.5. EXPENDITURES ON CURRENT RESOURCES AND LABOUR: AVERAGES FOR THREE YEAR PERIODS, SINCE 1950. SOUTH AFRICA.

Year	Labour	(Million Rands)						
		Current inputs						
		Ferti- lizers	Farm feeds diets & sprays	Fuel	Packing material	Building and fencing material	Repairs of machinery and implements	Seed, crop insurance licences other expenditure
1950-52	94.6	15.9	22.2	21.8	11.6	4.9	15.7	13.4
1953-55	122.3	19.0	30.4	27.9	16.7	5.6	21.5	16.7
1956-58	123.7	26.1	37.9	34.7	18.8	5.8	28.1	21.8
1959-61	138.1	33.0	50.0	44.3	22.0	10.6	33.3	35.4
1962-64	144.1	42.6	52.7	42.1	29.1	8.3	40.0	40.9
1965-67	153.0	53.8	71.0	45.4	30.4	9.9	43.8	45.6

Source: Unpublished data of the Division of Agricultural Marketing Research. 1970.

Tractors, fertilizers and lorries experienced by far the most spectacular increase in use. There has been some kind of parallel or complementary relationship in the application of fertilizers and the increase of tractors. Lorry numbers appear to have reached a maximum in 1959/60. In the U.S.A., tractor sales have decreased absolutely since 1960 (101). The demand for a durable item consists of two parts. The first is replacement demand and the second, the desire to equate current and desired stocks. In South Africa the replacement demand for tractors is getting more important. It appears that the desired stock of lorries has been reached and that the only demand is to replace depreciated stock. Tractors and trailers may also have replaced lorries because lorries are very costly when compared to tractors.

TABLE 3.6. PERCENTAGE CHANGES OF INPUTS OF MAJOR CATEGORIES WITH 1949/50 AS BASE

Year	Tractor numbers	Lorry numbers	Fertilizer plant nutrients **	Machinery at constant prices	Fixed improvements at constant prices	Fuel and repair charges at constant prices	Other operating inputs at constant prices	Regular employees *	
								Numbers	
								European labour	Bantu labour
1924/25	2								
1936/37	12	27							
1945/46	42	68	56					103	95
1949/50	100	100	100	100	100	100	100	100	100
1950/51	116	n.a.	100	107	108	104	107	87	96
1951/52	133	n.a.	96	114	98	104	111	74	91
1952/53	154	n.a.	112	119	98	104	111	73	94
1953/54	165	n.a.	135	133	106	118	132	63	96
1954/55	181	166	162	147	104	129	143	53	99
1955/56	194	156	158	149	106	136	150	61	99
1956/57	207	145	173	147	109	143	157	74	95
1957/58	220	147	193	147	113	150	157	90	95
1958/59	232	184	229	147	117	154	168	93	102
1959/60	246	222	234	147	121	175	179	89	100
1960/61	252	222	265	147	121	175	168	75	99
1961/62	262	222	293	147	123	175	175	98	101
1962/63	288	222	418	144	125	175	182	80	91
1963/64	312		466	144	126	171	182		
1964/65			471	144	128	175	189		
1965/66			464	149	126	175	186		

Sources: (1) Agricultural Census Reports 1924/25 - 1962/63.

(2) Unpublished data of the Division of Agricultural Marketing Research for later years.

* Managers, foremen and other regular employees.

** Index based on the quantities of N, P and K used.

The machinery input appears to have reached the desired level. These series may be seriously criticised because no allowance is made for quality or capacity of the unit.

It appears that census labour numbers for the earlier years are not directly comparable, and it was decided to consider only regular employees, including managers and foremen, because they constitute a more homogeneous category of the total labour input. Casual and seasonal labour were excluded. Regular European labour declined about 50% from the base level to 1954/55, but since then numbers of European employees have increased. Bantu regular labour numbers on the other hand, fluctuated very little over the period considered.

Operating inputs, other than fertilizer, have also showed a considerable increase since 1949/50, but they reached a virtually constant rate of use in real terms around 1959/60.

3.3. Price trends.

Resource substitution and the resulting input mix is greatly influenced by the factor-factor price ratios.

Price indexes of selected inputs are presented in Table 3.7. It is interesting to note that the prices of tractors and lorries trebled while the price of fuel doubled during the period under study. A part of the increase in price of tractors and lorries may however be attributed to an improvement in quality. Such capital items showed a marked increase from 1948 to 1955, partly because of the sterling devaluation in 1949 and partly because of inflation.

The price indexes presented in Table 3.8 are either not readily available or were calculated from primary sources. These indexes are thus given in a more detailed form. For example, the fertilizer price

index is derived from expenditures on fertilizers and total consumption of plant nutrients; the wage rates are derived from census data; and land prices from transfer data of rural properties.

The fertilizer price index of the Division of Agricultural Marketing Research was used for the period 1936/37 to 1951/52. The index for the period after that, was calculated from the total expenditure on fertilizer and the total consumption of plant nutrients. As a result of the substantial increase in the nutrient content of fertilizers, which the price index of Table 3.8 takes into account, this index is considerably lower for the last decade than the index of the Division

TABLE 3.7. INDEX OF PRICES OF FARMING REQUISITES, 1947/48-1949/50 = 100

Five year with mid-year	Tractors	Lorries	All implements	Pumping equipment	Spare parts	Farm feeds	Fuel
1940	66	50	61	n.s.	60	61	81
1945	79	68	76	n.s.	74	94	103
1950	116	120	117	105	117	105	114
1955	152	166	162	109	162	139	144
1960	160	190	178	129	174	147	161
1965	168	199	184	155	183	156	163

- Source:**
1. An abstract of agricultural statistics of the Union of South Africa. 1958. Division of Agricultural Marketing Research.
 2. Supplementary data to the abstract of agricultural statistics of the Republic of South Africa. Government Printer, Pretoria. 1969.

The percentage of nutrient content of all fertilizers sold increased from 10.4% in 1955 to 16.5% in 1966 (32). The decrease in the fertilizer price can also be attributed to an increased government subsidy.

This increase in subsidy was shown in Table 2.10. The price of plant nutrients has declined since approximately 1952/53 which is offered as the main factor contributing to the tremendous increase in the application of fertilizer as depicted in Table 3.6.

The interest on first mortgage bonds declined from 1936/37 up to 1944/45, but from then on the price of borrowed capital showed a continued increase. This can be expected to have some effect on investment even if it is only at the margin. Capital from savings was plentiful at the end of the War and opportunities for investment unlimited. Hence the relatively low interest rates in this period. The price of this type of capital in 1965/66 was 42% greater than the base year's price. Investment in machinery was at a very high level in the early fifties as a reaction to the demand that had accumulated during the war years, but no doubt also because of new and improved machine designs. As this demand was being satisfied, the rate of sales declined (29, p. 10/3). The possible effect of the interest rate on investment is fully explained in Chapter 6.

The wage rate of Bantu regular labourers was 63% higher in 1963 than in the base period while the wages of European regular labour showed an increase of 255% over the same period. The wage index for regular labour was computed from census data on regular labour employed and expenditure on regular labour. By deflating the wage rates of both groups by the consumer price index, the European real wage increased by 128% while the Bantu real wage increased only by 4%. Steenkamp (127, p. 96) warns against the use of the consumer price index for deflating Bantu wages because this index is "based on European family budgets, in

TABLE 3.8. PRICE INDEXES OF CERTAIN INPUT CATEGORIES IN SOUTH AFRICAN AGRICULTURE. BASE: 1947/48-1949/50 = 100.

Year	Machinery, tools and implements	Fertiliser	First mortgage bond interest rates	Land price weighted according to farms sold in different size groups	Land price weighted according to farms sold in the maize, wheat, cattle & sheep areas	Regular European labour (managers, foremen & other employees)	Regular Bantu labour (managers, foremen & other employees)	All Bantu & Coloured labour
	[a], [b]	[a], [b], [c]	[d]	[c]	[e]	[f]	[f]	[c]
1936/37	55	47	115	-	40	-	-	-
1939/40	62	56	116	-	39	-	-	-
1944/45	81	92	95	-	65	-	-	-
1945/46	78	95	95	89	64	65	105	-
1946/47	80	96	96	96	82	90	94	94
1949/50	114	104	102	106	109	110	106	103
1950/51	133	106	102	123	113	132	106	104
1951/52	146	135	111	140	143	153	107	125
1952/53	152	136	118	155	156	169	113	141
1953/54	152	132	120	171	165	184	119	149
1954/55	152	129	120	172	184	196	123	154
1955/56	154	136	127	187	219	226	112	165
1956/57	159	141	129	184	240	244	130	166
1957/58	163	136	129	208	222	262	139	172
1958/59	166	131	128	200	220	282	143	172
1959/60	169	131	129	204	216	292	145	188
1960/61	170	130	132	222	247	302	147	190
1961/62	171	125	135	233	253	313	149	194
1962/63	173	114	128	239	257	355	163	214
1963/64	175	105	127	275	285	-	-	247
1964/65	179	107	134	328	340	-	-	252
1965/66	181	112	142	355	365	-	-	269

Source:

- not available.

a Supplementary data to the abstract of agricultural statistics of the Republic of South Africa. January, 1961.

b An abstract of agricultural statistics of the Union of S.A. 1958.

c Transfers of rural and immovable property.

c Unpublished records of the Division of Agricultural Marketing Research.

d Union Statistics for 50 years.

f Census reports.

which foodstuffs figure less prominently than they do in Bantu household budgets". During the same period the index of all consumer items increased by 56% while that of food increased by 68%. It must also be borne in mind that Bantu labourers receive a part of their remuneration in kind.

Brand (10, pp. 248-282, 295-300) demonstrates that Lewis's classical model of economic development with unlimited supplies of labour, as refined by Ranis and Fei, can be used to interpret the development of the South African economy over the past four or five decades. The South African economy is of a dualistic nature with, on the one hand, a capitalistic and, on the other hand, a subsistence sector. Brand (10, p. 276) views Steenkamp's dividing line between the two sectors as the best. Steenkamp distinguishes between the areas owned by whites as the capitalist sector and the Bantu homelands, including the neighbouring territories not under South African control, as the subsistence sector. A portion of the Bantu population that lives on white farms may be added to the traditional sector, as a substantial number of those whose movements to cities are curbed, end up on farms (10, p. 276). Due to high population density and the relative dearth of capital in the subsistence sector, the marginal product of labour is very low, equal to zero, or even negative. The per capita production and consumption in this sector will usually be higher than the marginal product of labour but, nevertheless, low when compared with the per capita production in the modern sector (10, p. 249).

Workers in the traditional sectors are on absolute consumption levels that exceed the marginal product of labour in that sector. Consequently, the per capita consumption in the traditional sector, and not the marginal product there, will determine the supply price

at which each worker will be prepared to offer his labour services to employers in the modern sector. To compensate for the inconvenience involved in the transfer to the modern sector, a constant of 30% is added by Lewis to the per capita consumption level. The applicability of the model then implies that unlimited supplies of labour are available to the modern sector at this constant wage, explaining why the real Bantu wage remained virtually constant in the modern agricultural sector during the period under study.

Brand also (10, p. 267) states that Steenkamp's data on Bantu real wages cannot be taken to disprove a hypothesis that the real wage paid for unskilled Bantu labour in the modern sector of the South African economy remained virtually constant between the 'thirties and the end of the fifties'. Thus with the present restrictions imposed on the movement of labour to urban areas and the high population density and over supply of labour in the subsistence sector the real wage of Bantu labour cannot be expected to increase much in the near future.

It is difficult to say whether the reduction in European labour was due to the fact that European labour was getting more expensive and farmers substituted this resource with relatively cheaper inputs or whether the increase in the wage of European labour was due to the flow of Europeans to cities drawn by higher wages there. It can be expected that farmers introduced more non-White management to compensate for the decline in White managers and foremen. No figures could be found to substantiate this tendency. On the basis of production cost surveys, done by agricultural economists, the wage index of all non-White labour increased from 94 in 1946/47 to 269 in 1965/66.

The price of land increased $3\frac{1}{2}$ times from the base period to 1965/66. This increased value can partly be attributed to capital

invested in improvements. During the period studied, land was an excellent investment medium, with land prices outstripping the whole-sale price index. This is not seen as an inflationary occurrence but rather the product of greater production per acre, product prices and other factor prices. It can thus be expected that support prices will be capitalised into the value of the land.

Price ratios are shown in Table 3.9 for years in which data were available for most of the input categories.

By 1962/63 the price ratio of all capital items to European regular labour declined to approximately 50% of its base level but the ratio of all capital items to the Bantu regular labour price increased during the first half and then declined to the base price in 1962/63. Looking at relative prices alone, no pressure is put on the Bantu labour force to migrate to the cities as greater production will require increased use of resources. It must be borne in mind that 42% of the regular European labour force consists of managers while the Bantu managers are less than .01% according to the 1959/60 agricultural census. From this it may be deduced that the real substitution did not take place between European labour and capital but rather between Bantu labour and capital and between Bantu labour in the form of boss boys and European managers. European labour, other than managers and foremen can be expected to be substituted by non-White labour.

The fertilizer/land and fertilizer/labour price ratios demonstrate a spectacular decline explaining to some extent the greater application of fertilizer per unit of land.

The changing factor-factor price ratios suggest a continued change in the optimum resource mix for agriculture.

TABLE 3.9. INDEXES OF PRICE RATIOS FOR PARTICULAR CATEGORIES. SOUTH AFRICA, 1947/48-1949/50 = 100.

Year	<u>Fertilizer</u>	<u>Fertilizer</u>	<u>Capital</u>	<u>Capital</u>	<u>Land</u>	<u>Land</u>	<u>Interest rate</u>	<u>Interest rate</u>	<u>Fertilizer</u>	<u>Machinery</u>	<u>Short term requisites</u>	Parity ratio
	Land	Labour **	European regular labour *	Bantu regular labour *	European regular labour	Bantu regular labour	European regular labour	Bantu regular labour	Crops	Crops	Machinery	
36/37	84	-	-	-	-	-	-	-	101	119	90	-
39/40	103	-	-	-	-	-	-	-	130	144	89	64
44/45	102	-	-	-	-	-	-	-	107	95	114	78
45/46	107	-	129	80	136	84	146	90	103	85	119	83
46/47	100	101	96	91	107	102	106	102	96	80	116	96
49/50	98	101	99	103	91	100	93	97	99	108	93	99
50/51	86	102	94	116	94	116	78	96	90	113	86	115
51/52	97	108	93	132	91	131	72	104	104	113	89	98
52/53	88	97	87	129	92	136	70	104	96	107	90	104
53/54	77	89	78	120	93	144	65	100	96	110	87	106
54/55	75	84	74	118	88	140	61	98	94	111	87	103
55/56	73	82	65	132	83	166	56	113	100	114	87	101
56/57	77	85	62	116	76	141	53	99	105	119	87	102
57/58	65	79	59	111	80	150	49	93	99	119	85	100
58/59	66	76	55	108	71	140	45	90	97	122	85	96
59/60	64	70	54	108	70	141	44	89	96	124	86	96
60/61	59	68	53	109	73	151	44	99	94	123	87	94
61/62	54	64	52	108	74	156	43	91	89	122	88	93
62/63	48	53	46	100	67	147	36	79	84	127	88	93
63/64	38	43	-	-	-	-	-	-	74	123	86	98
64/65	33	42	-	-	-	-	-	-	71	119	85	102
65/66	32	-	-	-	-	-	-	-	73	118	87	102

Source: (1) Table 3.8.
 (2) Supplementary data to the abstract of agricultural statistics of the Republic of South Africa, January, 1969.
 (3) An abstract of agricultural statistics of the Union of South Africa, 1958.

* Capital items include tractors, lorries, implements, pumping equipment, fencing material and building material.

** Labour wage rate is based on cost of production surveys and refers to all non-White labour.

The factor/product price ratios of fertilizer to crops decreased indicating that the optimum levels of application per unit of land moved higher and higher.

Machinery prices increased at approximately the same rate as crop prices with the exception of during the post-war years. The ratio of the prices of variable cost items like short term requisites to the price of a fixed cost item like machinery remained virtually constant from 1949/50 onwards.* A change in the ratio is important because farmers can only produce in the short run as long as product prices are above variable costs. Between 1913 and 1940 the index of producers' prices of agricultural products fluctuated without showing any net gain over the period. Since then product prices improved except when the index of prices received remained virtually unaltered between 1952/53 and 1962/63. The index of farming requisites** is only available from 1940 and since then this index has increased gradually. The parity ratio, which is the ratio of all prices received to all prices paid, increased from 1939/40 to 1946/47. From then onwards it has remained constant for all practical purposes (Table 3.9). It is thus wrong to talk about a price-cost squeeze in South African agriculture. The price ratio did increase or decline for a few consecutive years, which was however, not enough for a trend to be established. It is quite possible that a cost squeeze does exist for certain individual

* The price index of short term requisites is a weighted price index of fertilizers, fuel, farm feeds, packing material and dips and sprays.

The price index of machinery is a weighted price index of tractors, lorries, implements, pumping equipment, spare parts and repair charges.

** An index of all requisites combined, excluding labour was used for this purpose.

enterprises.

Absence of a price cost squeeze in South Africa may have been the result of agricultural price policy under the Marketing Act. Price determinations are on an ad hoc basis bearing relationship to supply and demand factors, and are not made in terms of an arbitrary "parity" formula, which does not allow for technological changes and other supply and demand adjustments. In the case of fertilizer it was actually shown that the ratio of fertilizer prices to crop prices decreased. The price cost squeeze, however, has been a reality in the U.S.A. where the parity ratio has fallen from 1910, with the exception of a brief rise in the nineteen forties. The parity ratio in the U.S.A. drifted downwards from 1910 until 1940 but by 1950 temporarily recovered almost to the 1910 level (101, p. 13).

3.4. Farm income.

Gross income per farm in South Africa showed a parallel increase to that of the U.S.A., with the South African income figures per farm marginally higher than that of the U.S.A. A comparison of farm income in South Africa is made with that of the U.S.A. because it is generally accepted that the U.S.A. has already advanced far on the road of economic development. A comparison of this kind must be treated with caution because product price levels in the countries compared may differ substantially.

Cash income and farm consumption minus wages, salaries and rent in real terms increased by approximately 40% from 1950 to 1965 in South Africa. The higher income per farm in South Africa was partly due to a decrease in number of farms and partly due to increased productivity. The total number of farms in South Africa decreased from 116,848 in 1950 to 104,681 in 1962, while gross value of agricultural production

TABLE 3.10.

INCOME PER FARM FOR SOUTH AFRICA AND U.S.A.

Year	Cash income and farm consumption minus wages, salaries and rent. South Africa	Gross income per farm for South Africa	Gross income per farm for the U.S.A.	Cash income and farm consumption minus wages, salaries and rent, deflated by consumer price index (1947/8 - 1949/50=100) South Africa
	(a)	(b)	(c) (d)	(a)
	(Rands per farm)			
39/40	n.s.	1,350	1,250	n.s.
44/45	n.s.	2,197	3,107	n.s.
49/50	3,291	3,758	4,137	3,177
54/55	4,665	6,220	5,153	3,510
59/60	5,467	7,505	6,911	3,672
60/61	5,564	7,980	7,472	3,677
61/62	6,378	8,151	7,988	4,139
62/63	6,446	8,644	8,404	4,129
63/64	7,499	9,014	8,127(e)	4,734
64/65	7,390	9,680	8,576(a)	4,488

- Source: (a) Unofficial records of the Division of Agricultural Marketing Research.
- (b) Gross value of agricultural production was used for this purpose.
- (c) Includes government payments. (R1 = \$1.39).
- (d) Minden, J.A. (1965). Domestic demand function for new farm machinery. Unpublished Ph.D. thesis. Iowa State University, p. 10.
- (e) Gross income is calculated on the basis of the total production index and on an index of all agricultural product prices. Production Yearbook, 1968. Food and agriculture organisation of the United Nations.

increased from R439 m in 1950 to R1,016 m in 1965. The decrease in the number of farming units may also be ascribed to a change in the method classifying farms, for example since the 1956/57 census, holdings used for residential purposes were omitted (16). Gross income per farm is calculated at R2,300 for Germany for 1959/60 which is lower than the South African or American figures (38, p. 263).

The agricultural economic system is such that the real gains from the adoption of new technologies are, in the absence of price supports, often completely passed on to the consumer. The technological movement of the supply curve to the right will result in a lower consumer price and theoretically, to lower farm income when demand is inelastic. Farmers have, however, according to Table 3.10 realised some of the gains of economic progress. It may be argued that the overall demand curve for South African products is fairly elastic since about 40% of the total production is exported. The prices of these export products are however not determined by the local demand and supply but by world demand and world supply.

3.5. Structural change in farm size.

In the U.S.A. the average acreage of all census farms increased by 90% between 1930 and 1960 (76, p. 17). For the same period the average farm size for South Africa remained constant. The decline in the number of farmers in the U.S.A. has been greatest for units too small to (a) provide an adequate family income, and (b) realise scale economies from mechanisation (76, p. 17).

TABLE 3.11. NUMBER OF FARMS ACCORDING TO SIZE. 1920 - 1962. SOUTH AFRICA.

Size group (in hectares)	1930	1935	1939	1946	1950	1955	1960	1962
	Numbers							
0 - 85	20,873	22,632	25,320	30,307	34,541	34,765	31,434	33,447
86 - 1713	63,121	65,335	68,970	69,779	70,682	64,919	61,079	59,328
1714 and over	10,955	11,299	11,339	11,721	11,377	11,881	13,301	13,175
Total number ^(b)	96,940	101,277	107,536	112,453	116,848	111,586	105,859	104,681 ^(a)
Hectares per farm (all farms)	854	839	803	788	743	784	867	855 ^(a)
	Percentage of farms							
0 - 85	21.5	22.3	23.5	27.0	29.6	31.2	29.7	32.0
86 - 1713	65.1	64.5	64.1	62.1	60.5	58.2	57.7	56.7
1714 and over	11.3	11.2	10.5	10.4	9.7	10.6	12.6	12.6

Source: (1) Agricultural census reports. Report on agricultural and pastoral production. Bureau of Statistics.

(2) Handbook of Agricultural Statistics 1904-1950. Government Printer, Pretoria.

(3) Union Statistics for 50 years. 1910-1960. Bureau of Census and Statistics, Pretoria.

(a) Figures refer to 1963.

(b) Undivided farms are included with the total number of farms, but omitted from the subgroups.

Many reasons may be advanced why farms of different sizes persist side by side over time, if constant returns to scale do not exist. When labour is abundant, nearly constant costs may prevail and not much can be gained by spreading the fixed costs of machinery over a larger unit through consolidation of farms. In South Africa the factor-factor price ratio, price of land/wage of Bantu labour increased from an index of 84 in 1945/46 to an index of 147 in 1962/63. The price ratio of capital to Bantu labour also increased, but slipped back to the base period level in 1962/63.* This indicates, that if the marginal rate of substitution between resources is kept constant, that no real economic pressure existed to realise scale economies from mechanisation** in South Africa. In the U.S.A. the price of machinery/price of labour decreased by 50% from 1930/39 to 1950/59 and the price of land/price of labour decreased by 44% in the same period putting an economic incentive on the American farmer to acquire more land (76, p. 10). This may explain to some extent why the size of the average American farm increased by 90% from 1930 to 1960 while in South Africa it remained constant. Also, European farmers have a monopoly right to land. They cannot give up their land unless their farms are consolidated into other European-owned farms. Product price supports in the two countries may

* The capital/European labour and land/European labour price ratios decreased, but since European hired labour is only a small proportion of the labour force, it can be ignored here. In 1962/63 the European regular labour constituted 1.8% of the regular European and Bantu labour force combined. European labour probably has a managerial rather than a labour function.

** The marginal rate of substitution of labour and capital, and labour and land, must have changed with increased production per unit of land (better varieties, etc.), higher quality machines and the better education of the labour force.

have had an effect on farm sizes. Produce price supports, however, are expected to have little effect on the resource allocation, but rather to determine the intensity of all resources used.

The writer's opinion is that farm sizes will adjust to an optimum according to technological development without any outside interference. Government attention should be directed to forces that prohibit adjustment such as ignorance, lack of capital and subdivision of land for speculative purposes.

Farms over 1,714 hectares (2,000 morgen) reported in Table 3.11 increased from 10,955 in 1930 to 13,175 in 1962. This is a percentage increase of 11.3% to 12.6%. On the other hand farms smaller than 85 hectares increased from 20,873 in 1930 to 33,447 in 1962 which is an increase from 21.5% to 32.0%. This definitely justifies the concern of the State. Groenewald (62, p. 10) also mentions examples where un-economic farm units contributed to soil deterioration. The Commission of Inquiry into European occupancy of rural areas concluded that both large and small farms encourage the depopulation of the White plateau and result in inflationary prices of land (138, p. 29).

In commercial farming areas farm consolidation can take place, with often only a slight increment of labour, because of the surplus capacity of farm machinery. The remaining operators usually have more capital at their disposal and can acquire more of other inputs such as fertilizer and feed. This should shift the demand curve for some resources to the right. Farm size is thus affected by the structure of the resource demand and in turn resource demand may be influenced by a changing pattern of farm size.

The survivor technique may shed some light on the optimum

size of farms if farms are cross tabulated as in Table 3.11, for homogeneous areas. According to this technique the optimum farms survive in the long run while farms greater or smaller than the optimum size go out of business. Farms of the optimum size are thus expected to increase at the expense of farms greater or smaller than the optimum size.

The Department of Agriculture and Fisheries for Scotland, discussing the "Structure of Agriculture" in the United Kingdom, classified farms in size groups not in terms of acreages but in terms of standard labour requirements. The requirements are expressed in terms of "standard man days" which represent eight hours of manual work for an adult male worker under average conditions. Holdings were further classified as large, medium-sized, small and very small with "standard man days" requirements of 1,200 or more, 600-1,199, 275-599 and under 275, respectively (27, pp. 5-7).

CHAPTER 4.

AGGREGATE AND REGIONAL PRODUCTION FUNCTIONS

In this chapter production functions for the agricultural industry and for individual agro-economic regions are reported.

4.1. Aggregate production functions

Aggregate production functions are estimated from time series and from cross-sectional data.

4.1.1. Aggregate cross-sectional production functions

The aggregate and regional cross-sectional production functions presented in this chapter are based on the 1959/60 agricultural census, which was chosen because it is the most comprehensive of recent reports. Usually a better estimation is obtained from cross-sectional data than from time series data in a production function because of the high correlation between time series variables. Cross-sectional analysis measures the potential response at a point in time in contrast to time series which is based on observed changes in response over several periods (20).

The inputs and outputs for the different magisterial districts, represent aggregations of all farms on the assumption that agricultural resources and farming conditions and practices are relatively uniform within a district. Data for the Transkeian territories and Zululand were not included largely because of the relatively high ratio of Bantu to White holders for these areas. All the variables are averages per commercial farm, and the numerous items that had to be added together to get the inputs for this production function analysis are given in the appendix. A major part of this work was done by the

Division of Agricultural Marketing Research who have used some of these data for regional income purposes. A brief description of the variables is given below :-

Output (Y)

Value of farm production per commercial farm is taken as the measure of output. This figure includes the value of products sold and products used on the farms.

Current expenditure (X_1)

Most of these inputs are depleted during the course of one production season and are thus of a short term nature, with the exception of repairs to machinery, buildings and fencing.

Labour (X_2)

This includes cash wages, salaries and payments in kind of White and non-White labour. It is thus assumed that the expenditure on labour is in accordance with the productivity and quality of that labour. Griliches (49, pp. 8-20) showed that when labour is measured in physical numbers, there is a tendency to overestimate capital and to underestimate labour because of the correlation between labour quality and capital. This will be the case if labour numbers do not take into account quality differences. If the expenditure on labour is used instead of labour numbers then the labour input does take into account quality differences.

An alternative approach is to measure White and non-White labour separately. Becker (3) found that by incorporating a discrimination factor into the capital variable a better model can be obtained. He estimated production as a function of labour and capital for White and non-White labourers separately. An additional factor was included in the capital variable which indicated that

economic discrimination reduces incomes of both Whites and non-Whites.

A measure of the labour input actually used is required and not a measure of total labour available during the production period (73, pp. 222, 223). Thus another advantage of using labour expenditure data as in the present study is that this is also an indication of the labour utilized.

Machinery, tools and implements (X_2)

Depreciation charges are as reported in census reports and a 6% interest rate was used to transform the capital inputs to service flow units.

Land (X_4)

A 9% interest rate on the value of land was used as a measure of the flow resource of land. Real estate values were obtained from the 1960/61 agricultural census. Since the percentage remains the same for all the different magisterial districts, the regression results would remain unchanged if stock values were used instead. The production elasticities are not affected by the size of the interest rate.

Livestock (X_5)

An interest charge of 6% on livestock was used but there was no depreciation charge.

The ideal way of measuring the flow of capital services is by using data on work performed by capital assets, but it is impossible to obtain these on a macro-economic scale. For this reason the capital stock variable has been almost exclusively used in production studies as a proxy of the capital input. If service flows are proportional to capital stocks, then it would be immaterial which of the two concepts is used in a Cobb-Douglas production (double logarithmic) function. Yotopoulos (151, pp. 476-491) showed that the practice of

deriving the service flow input from stock value by applying a fixed interest charge is incorrect.

- "(1) whenever assets vary in their durability;
- (2) whenever their age or vintage distribution is uneven, and
- (3) when the magnitude of productive services varies with the age of the asset itself."

In this study, depreciation charges for machinery, tools and implements were used and it was not necessary to make the proportionality assumption for this factor.

Percentage of income from livestock (X_6)

This variable is the percentage of income from the livestock enterprises in terms of all income from the farm. The percentage of income from livestock was never transformed to logarithms in the subsequent models.

The first estimate is a production function for the Agricultural Industry based on all the above-mentioned factors. A strong correlation between current inputs and machinery exists which has made it impossible to estimate these variables separately. The simple correlation coefficient being r_{13} , .836 and the partial coefficient, $r_{13.2456}$, .775. In order to get rid of the multicollinearity it was decided to pool the two variables and treat them as one which may be justified on economic grounds, as a strong positive correlation is an indication of a close relationship. It is interesting to note that Heady (73, p. 222) treated the same problem in the same way. Heady found a high correlation between machinery and equipment inputs and fuel and lubricants. These items were consequently grouped together to form a single input category. The production function should be specified in such a way that the inputs within an individual category

are as nearly perfect substitutes or perfect complements as possible while relative to each other, the categories of inputs are neither perfect substitutes nor perfect complements (73, p. 220). This leads to a more meaningful specification of the production problem.

The regression coefficients and their corresponding t values for three alternative models are shown in Table 4.1. The following variables were at least significant at the 1% level; labour, current expenditure and machinery, livestock and percentage of income from livestock.

The negative coefficient of the land variable in Table 4.1 may partly be attributed to multicollinearity. Simple correlations of $r_{14} = .636$ and $r_{24} = .568$ were high in comparison with the other inter-factor correlations. The t -value for land in equation 4.1 was only 0.09. This variable will be further tested in the more complex model 4.4.

When the percentage of income from livestock variable is introduced in equation 4.1, the R^2 increased from .549 to .675 in equation 4.1. This variable was added to take into consideration differences in farming organisations. It was highly significant in equation 4.1; it made the coefficient of livestock more significant and forced the elasticity of land in the expected direction (see Table 4.1).

All the variables are highly significant in equations 4.2 and 4.3. In both models the land variable turned negative with regression coefficients more than three times the standard error. Equation 4.3 is the traditional production function estimating the separate influences of land, labour and capital. The t -value of capital items is more than twenty which is exceptionally high.

When the elasticities for current inputs and machinery, labour,

TABLE 4.1. REGRESSION COEFFICIENTS OF PRODUCTION FUNCTIONS FOR SOUTH AFRICA 1959/1960.

Equation	R ²	Constant	df	Current expenditure and machinery $X_1 + X_3$	Current expenditure machinery and livestock $X_1 + X_3 + X_5$	Labour X_2	Land X_4	Livestock X_5	Percentage of income from livestock* X_6	Σ elasticities
4.1 ^(a)	.675	- .353	229	.3564 (t = 4.93)		+ .1996 (t = 2.74)	- .0064 (t = 0.09)	+ .3957 (t = 11.57)	- .0077 (t = 5.74)	.945
4.2 ^(b)	.549	- .167	230	.4265 (t = 6.58)		.3916 (t = 6.12)	- .2304 (t = 3.27)	+ .2512 (t = 8.72)	-	**
4.3 ^(b)	.746	1.144	231		.9512 (t = 21.22)	.2035 (t = 5.29)	- .1947 (t = 4.10)			**

(a) All variables are transformed to logarithms except X_6

(b) All variables are transformed to logarithms

* The total correlation between land and percentage of income from livestock, $r_{46} = .23$ which may be considered as low.

** As a result of the negative land values, the returns to scale were not shown.

land and livestock are added together, the returns to scale is equal to .945 in equation 4.1.

Because of the immense differences in natural conditions in South Africa, dummy variables were introduced into the model to account for some of the differences amongst agro-economic regions.

Dummy variables will only be effective in production models if the production functions have the same elasticities for the various regions but are on different planes above one another. Regional models reported in this study show variations amongst regions so that the scope of dummy variables is limited in this analysis.*

Variables X_7 up to X_{16} represent dummy variables for each of the Agro-economic regions.**

$X_7 = 1$ if A region, 0 otherwise $X_8 = 1$ if B region, 0 otherwise

$X_9 = 1$ if C region, 0 otherwise $X_{10} = 1$ if D region, 0 otherwise

$X_{11} = 1$ if E region, 0 otherwise $X_{12} = 1$ if F region, 0 otherwise

$X_{13} = 1$ if H region, 0 otherwise $X_{14} = 1$ if K region, 0 otherwise

$X_{15} = 1$ if M region, 0 otherwise $X_{16} = 1$ if S region, 0 otherwise

If $X_7 = X_9 = X_{10} = \dots \dots \dots X_{16} = 0$, then V region.***

* Johnston (83, p. 223) shows that changes in slope of the regression can be measured using dummy variables by introducing an interaction term involving the dummy variable and the X variable. This technique, however, is only practical when the number of dummy variables and other independent variables are few. With the large number of dummy and other variables presented in this analysis it would not be possible to estimate all the possible interaction terms.

** For a discussion of the Agro-economic regions see Section 2.3.

*** Care was taken to ensure that the matrix of sums of squares and cross products ($X^T X$) remains non singular by dropping the variable for the V region. Another approach would be to eliminate the intercept term and fit the model with all the dummy variables. In the conventional computing programmes the intercept term is automatically computed and the latter procedure consequently breaks down since the matrix cannot be inverted.

These variables cannot be transformed to logarithms because of their zero-one nature.

Due to the partial success of introducing the percentage of farm income from livestock into model 4.1 it was decided to experiment further with this variable and to make more allowance for differences in the output mix. It stands to reason that livestock inputs and current inputs may have different marginal products on livestock and crop producing farms.

It was stated earlier that with the introduction of dummy variables it was assumed that the production functions for different regions have the same elasticities but that they can be on different planes. By making the coefficients dependent on the output mix, an allowance can be made for different marginal products of the same factor for different regions.

$$\begin{aligned}
 \log Y = & - .2412 + .7303 \log (X_1 + X_3) - .006318 X_6 \log (X_1 + X_3) \\
 & \quad (t = 4.48) \quad \quad \quad (t = 2.50) \\
 & + .002950 X_6 \log X_2 + .0847 \log X_4 - .002536 X_6 \log X_4 + 0.1009 \log X_5 \\
 & \quad (t = 1.29) \quad \quad (t = 0.50) \quad \quad (t = 1.08) \quad \quad (t = 1.40) \\
 & + .005177 X_6 \log X_5 - 0.1084 X_7 - .1447 X_8 - .3310 X_9 - .4331 X_{10} \\
 & \quad (t = 4.51) \quad \quad (t = .76) \quad (t = 1.00) \quad (t = 2.16) \quad (t = 2.62) \\
 & - .3754 X_{11} - .1968 X_{12} - .0436 X_{13} - .2692 X_{14} - .1792 X_{15} - .4300 X_{16} \\
 & \quad (t = 2.48) \quad (t = 1.11) \quad (t = 0.30) \quad (t = 1.63) \quad (t = 1.14) \quad (t = 2.79)
 \end{aligned}$$

4.4

 $R^2 = .707$

df = 217

In model 4.4 the variables can be specified as follows: current expenditure, X_1 ; labour, X_2 ; machinery, X_3 ; land, X_4 ; livestock, X_5 , and percentage of income from livestock, X_6 . The other variables are

dummy variables representing Agro-economic regions. The joint hypothesis that all the dummy variables are zero was rejected at the 1% level.

$$F_{10, 217} = \frac{\text{additional reduction in sum of squares} / \text{number of dummy variables fitted.}}{\text{due to dummy variables.} \quad \text{residual mean square}}$$

$$= \frac{2.382/10}{.0952} = 2.50$$

The dummy variables may be interpreted as an index of technical efficiency (80, p. 48). As such these variables may indicate that resources are used more efficiently in certain regions than in others. The partial regression coefficients of the dummy variables show the resource productivity of the regions estimated in terms of another. It appears as if resources are used less efficiently in the following regions, C, D, E and S. In these regions livestock plays a prominent rôle (see Table 2.8). In the following crop producing regions resources are used more efficiently; A, B, H and K. This implies that given the same amount of resources a greater output is obtained on farms where the greater percentage of income is from crops.

In this context it is of interest to note that Groenewald (61) showed that primary resources in crop and fruit farming increased by approximately 50% while the index of resources used in livestock farming remained constant during the period 1945/46 till 1962/63. Groenewald, however, could find no significant difference in the increase in the physical yield per unit of primary production for the three sectors. The coefficients of the cross product variables ($X_6 \log X_2$, $X_6 \log X_4$... etc.) can be expected to be positive for livestock associated inputs and negative for crop associated production factors. Current inputs and machinery are used mainly on a crop

producing farm and from the above equation it can be seen that the coefficient of $X_6 \log(X_1 + X_3)$ is negative. Livestock inputs are of more importance on a livestock farm explaining the positive sign of the coefficient of $X_6 \log X_5$. Thus the more important livestock is in an agro-economic region the higher will the coefficients of livestock be and the lower the inputs not associated with livestock enterprise.

Table 4.2 shows the elasticities of production factors for a livestock farm with no crops, a crop producing farm with no livestock, and a farm with the average mix of crops and livestock.

TABLE 4.2. PRODUCTION ELASTICITIES OF CURRENT INPUTS AND MACHINERY, LABOUR, LAND AND LIVESTOCK FOR: A LIVESTOCK FARM, A CROP PRODUCING FARM AND A FARM WITH AN AVERAGE MIX.
SOUTH AFRICA, 1959/1960.

Types of farms	INPUTS				
	Current inputs and Machinery ($X_1 + X_3$)	Labour (X_2)	Land (X_4)	Livestock (X_5)	Returns to scale
Livestock farm (100% livestock)	.0985	.2950	- .1689	.6186	.8432
Crop farm (0% livestock)	.7303		.0847	.1009	.9159
Farm with average mix (59.91% livestock)	.3518	.1767	- .0672	.4111	.8724

The returns to scale for a crop farm is .9159 and for a livestock farm .8432, suggesting that the economies of scale are less on a livestock producing farm. It also appears as if land is more in "over supply" on a livestock farm than on a crop farm.

It is interesting to note the wide variations in elasticities (and thus marginal products) for the same factor for different types of farms. For example the elasticity of current inputs and machinery is .7303 on a crop farm and .0985 on a livestock farm. The elasticity of livestock is .6186 on a livestock farm and .1009 on a crop farm. The elasticity of labour is not shown for the crop farm because the coefficient of $\log X_2$ was found to be non significant in model 4.4. The coefficient of $X_2 \log X_2$ in the same model becomes zero for a crop farm (0% livestock).

Looking at the elasticities for the average mix farm and comparing this with equations 4.1 and 4.2, it can be seen that by allowing the output mix to vary, the livestock input has been given a much more prominent rôle at the cost of inputs not associated with livestock. Labour also suggests a much higher marginal product on a livestock than on a crop farm which may be because labour cannot be substituted to the same extent on a livestock farm as on a crop producing farm. Haddy and du Toit also found a high marginal product for labour on cattle ranches in the Eastern Kalahari region (73, p. 605).

Land indicates a positive marginal product on a crop producing farm but a negative marginal product on a livestock farm. By allowing for differences in output mix Griliches (55, p. 426) found a similar result. His result is concealed in a table. However, he did not find a negative coefficient for the average farm which may be the reason why he did not refer to it. On a farm of the average mix the land variable again turns out to be negative. This result is encouraging and tends to explain and support the negative marginal product of land found in equations 4.1, 4.2 and 4.3.

4.1.1.1. Estimation of the production function using principal components.

The object of component analysis is to economize in the number of variates. To achieve this linear transformation of the following type are sought where p variates $X_1 \dots X_p$ are observed on

$$Z_i = \sum_{j=1}^P a_{ij} X_j \quad i = 1 \dots P \quad 4.5$$

n individuals (86, p.10) (96, pp. 36-40).

The coefficients a_{ij} are chosen so that the new variate Z_1 has as large a variance as possible; the second Z_2 is chosen to be uncorrelated with the first and to have as large a variance as possible; and so on. The X variates are thus transformed to new uncorrelated variates which account for as much of the variation as possible in descending order.

A principal component analysis throws light on the following problems; (a) how many variables should be taken (b) how to get rid of multicollinearity. Because of high intercorrelations between explanatory variables previously mentioned, this analysis was carried out on the resource use and production data of the 235 magisterial districts obtained from the 1959/60 Agricultural Census.

Latent roots and coefficients of the linear orthogonal transformations are presented in Table 4.3.

The largest root $\lambda_1 = 2.74$, thus the first orthogonal variate (Z_1) accounted for $\frac{2.74}{6} \times 100 = 46\%$ of the variation in resource use. The first two components accounted for 69%, the first three components for 83% and the first four components for 93%.

The effective dimension of the variation can thus be reduced

TABLE 4.3. LATENT ROOTS AND COEFFICIENTS (a_{ij}) OF LINEAR TRANSFORMATIONS. NUMBER OF OBSERVATIONS = 235.

λ	X_1	X_2	X_3	X_4	X_5	X_6
Latent roots	Current expenditure	Labour	Machinery, tools and implements	Land	Livestock	Percentage of income from Livestock
2.7404	.5192	.4848	.5415	.4245	-.0686	-.1314
1.3109	.1045	-.1666	-.0286	.4086	.4830	.7485
.9079	.1289	.0558	.0532	-.2763	.8579	-.4063
.6304	-.4978	.5854	-.4140	.4450	.1361	-.1468
.2765	-.3202	-.5819	.3087	.5456	.0512	-.4040
.1339	-.5938	.2298	.6606	-.2841	.0695	.2695

from six variables to three or four variables.

The first component according to Table 4.3 is

$$\zeta_1 = .5192 X_1 + .4848 X_2 + .5415 X_3 + .4245 X_4 - .0686 X_5 - .1314 X_6$$

and the second component is

$$\zeta_2 = .1045 X_1 - .1666 X_2 - .0286 X_3 + .4086 X_4 + .4830 X_5 + .7485 X_6$$

4.6

The other components can be read off in the same way from Table 4.3.

Through inspection of Table 4.3 it appears as if the following four linear combinations of variables account for about 90% of the variation in the resource data. These transformations are obtained by using variables with similar or dominant coefficients. For example to obtain

$$\zeta_1 = X_1 + X_2 + X_3 + X_4$$

$$\zeta_3 = -X_4 + X_5 - X_6$$

$$\zeta_2 = X_4 + X_5 + X_6$$

$$\zeta_4 = -X_1 + X_2 - X_3 + X_4$$

4.8

the first transformation (ζ_1) it can be seen from Table 4.3 that the coefficients of X_1 , X_2 , X_3 and X_4 are all approximately equal while the coefficients of X_5 and X_6 are comparatively small.

From these linear transformations a very interesting result emerges, namely, that the crop associated inputs (X_1 , X_2 , X_3 and X_4) tend to group together in ζ_1 and ζ_4 while the livestock associated inputs tend to group together in ζ_2 and ζ_3 . The land input appears in all the components probably because land is a common input to both enterprises. The variables appearing in ζ_3 and ζ_4 are negative because the variance of two variables can be explained by their totals and their difference. The grouping appears to be natural and variables in the group are complementary. If desired, the data may now be pooled according to the natural groups before applying multiple regression analyses. This was not done as the presence of the land variable in both ζ_1 and ζ_2 made it difficult to interpret these groups in an economic way. This principal component analysis highlights again the estimation problem arising from the fact that the bigger farms use more labour, more machinery and more current expenditure than the smaller farms.

In many cases, the components do not have an identifiable separate existence. Kendall (86, pp. 26, 27) reports a study undertaken by Stone, where the latter tried to interpret his components. Stone correlated his components with the original variables and found that the components could be identified by an equal number of original variables. This may be useful for example in a demand model where the complex of other prices can be presented by a component or two.

In the present study, interest is centred at the estimation of a model

$Y = \beta_0 + \beta_1 X_1 + \dots + \beta_p X_p + \epsilon$ where Y is production, the X_i 's are resource inputs and ϵ is a random error.

Having done a principal component analysis on the variables $X_1 \dots X_p$, Y may now be written as a function of the new components ζ_1 where the α 's are linear functions.

$$Y = \sum_{j=0}^P \alpha_j \zeta_j + \epsilon \quad 4.9$$

of the β 's.

The α 's for the model in question were computed using the procedure outlined by Stone and reported in Kendall (86, pp. 72, 73). The simple correlations between Y and the X_i 's are as follows: $ry1 = .4353$, $ry2 = .2360$, $ry3 = .2370$, $ry4 = .1040$, $ry5 = .8187$ and $ry6 = .0620$. In order to calculate α_1 the regression coefficients of the X variables in model 4.6 are also required.

$$\alpha_1 = \frac{\sum Y \zeta_1}{\lambda_1} = \frac{1}{2.7404} \left((.4353)(.5192) + (.4848)(.2360) + (.2370)(.5415) + (.1040)(.4245) + (.8187)(-.0686) + (-.0620)(-.1314) \right) = .1696$$

Similarly, the other α 's were computed as

$$\alpha_2 = .2982$$

$$\alpha_3 = .8599$$

$$\alpha_4 = -.0157$$

With the variance of Y equal to the one, the contribution of ζ_1 to the total variance is $\lambda_1 \alpha_1^2$. The first four components contributed the following percentages to the total production variance

$$\zeta_1 = 7.88\%$$

$$\zeta_2 = 11.66\%$$

$$\zeta_3 = 67.13\%$$

$$\zeta_4 = .02\%$$

The first three components explained 86.67% of the variance in production. The fourth component was dropped because of its insignificant contribution.

The production function can now be determined by substituting for the α 's and ζ 's in model 4.9

$$Y \text{ (about its mean)} = .2301 X_1 + .0805 X_2 + .1291 X_3 - .0437 X_4 + .8700 X_5 - .1485 X_6$$

$$R^2 = .867$$

$$df = 228$$

$$4.10$$

It is very interesting to note that the land variable (X_4) again turned negative. This confirms earlier results estimated by multiple regression. The signs of the other factors of production (X_1 , X_2 , X_3 and X_5) are as expected. The sign of X_6 can be either positive or negative as this variable measures the percentage of income from livestock. Using multiple regression it was earlier found not possible to estimate the separate effects of X_1 and X_3 . Due to high correlation, one of these variables always turned out negative. By orthogonalizing the X-matrix it does appear as if a more reasonable estimate is obtained as both variables are now positive.

From model 4.10 elasticities of production were calculated for X_1 , X_2 , X_3 , X_4 and X_5 respectively as .77, .13, .09, -.10 and .31. The variable input, current expenditure, appears to have by far the most important influence on production. On the other hand, the machinery elasticity is lower than expected.

4.1.2. Aggregate time series production function based on factor shares.

The traditional approach in the estimation of production functions is to estimate simultaneously in one model the partial contributions of the relevant inputs, on the basis of time series or

cross-sectional data. Because of multicollinearity, inputs have to be restricted to a limited number of highly aggregate variables like labour, capital and land. Due to the increase in cost it is usually not possible to increase the degrees of freedom to an extent sufficient to estimate more than four inputs.

Another approach is to estimate production functions by means of factor shares. The share of a factor in the total production is defined as the expenditure on this factor divided by the value of production. (133, pp. 219,220) (136, pp. 1462-1467) (137, pp. 613-631). This approach eliminates the tedious problem of multicollinearity, but assumes that an adjustment to equilibrium prevails in factor shares.

In equilibrium, the marginal product for a resource (A) in producing Y is equal to the factor/product price ratio.

$$\text{MP of resource A} = \frac{\partial Y}{\partial A} = \frac{P_A}{P_Y} \quad 4.11$$

If 4.11 is multiplied by AY^{-1} then the elasticity of resource A is equal to the factor share of resource A as in equation 4.12.

$$\text{Elasticity of A, } E_A = \frac{\partial Y}{\partial A} \cdot \frac{A}{Y} = \frac{P_A}{P_Y} \cdot \frac{A}{Y} = \text{Factor share of A (F}_A\text{)} \quad 4.12$$

YP_Y is taken as the gross value of agricultural production
and AP_A as the total factor expenditure.

On the basis of unpublished data of the Division of Agricultural Marketing Research, factor shares are computed and shown in Table 4.4 from 1949/50 - 1965/66.

Factor shares of labour, fertilizer, fuel and repair charges of all machinery, farm feeds and dips and sprays and other operating inputs were based on expenditure data. Land and livestock assets were converted to a flow input by taking 3% and 6% interest charges respectively. On all farm machinery 15% depreciation and 6% interest charges

TABLE 4.4. FACTOR SHARES FOR AGRICULTURAL INPUTS. SOUTH AFRICA, 1949/50 - 1965/66.

Year	Labour	Fertilizer	Land (5% interest)	All farm machinery (15% depreciation and 6% interest)	Livestock (6% interest)	Fuel and repair charges of all machinery	Farm feeds dips and sprays	Fixed improvements (6% interest and 4% depreciation)	Other operating inputs
49/50	.2067	.0352	.1322	.1153	.0672	.0755	.0273	.1257	.0427
50/51	.1574	.0270	.1094	.1042	.0513	.0639	.0208	.1046	.0338
51/52	.1991	.0326	.1433	.1382	.0665	.0838	.0251	.1347	.0420
52/53	.1804	.0274	.1292	.1211	.0625	.0681	.0218	.1130	.0372
53/54	.1838	.0268	.1347	.1270	.0639	.0728	.0208	.1076	.0412
54/55	.1879	.0314	.1443	.1418	.0656	.0819	.0238	.1107	.0440
55/56	.1693	.0340	.1439	.1397	.0628	.0814	.0245	.1107	.0435
56/57	.1604	.0341	.1345	.1293	.0613	.0818	.0240	.1040	.0422
57/58	.1774	.0389	.1470	.1422	.0723	.0940	.0249	.1160	.0452
58/59	.1872	.0410	.1453	.1393	.0715	.0929	.0324	.1152	.0455
59/60	.1698	.0422	.1450	.1319	.0665	.1016	.0318	.1109	.0488
60/61	.1642	.0409	.1480	.1280	.0644	.0975	.0318	.1094	.0515
61/62	.1705	.0458	.1467	.1264	.0634	.0964	.0345	.1106	.0589
62/63	.1578	.0450	.1434	.1001	.0602	.0915	.0344	.1076	.0557
63/64	.1534	.0512	.1467	.1166	.0610	.0876	.0352	.1077	.0526
64/65	.1460	.0492	.1422	.1098	.0595	.0816	.0341	.1022	.0504
65/66	.1419	.0513	.1441	.1089	.0601	.0792	.0348	.1015	.0518

were adopted, and for fixed improvements 6% interest and 4% depreciation charges were used.

According to Table 4.4 labour's share of the total output declined rapidly while the share of fertilizer, farm feeds and dips and sprays and other operating inputs increased. Factor shares of the remaining inputs did not show definite trends.

4.1.2.1. Estimation of elasticities by ordinary least squares.

If equilibrium quantities of resources are used then the factor shares in Table 4.4 are elasticities of production for the corresponding years. This equilibrium assumption is unrealistic and to avoid this it is assumed that the employment of a factor tends to an equilibrium level as will be shown by the following distributed lag model,

$$P_t - P_{t-1} = b [E_t^M - P_{t-1}] + U_t \quad 4.13$$

where P_t is the actual factor share in year t (expenditure on factor divided by total production), E_t^M is the equilibrium factor share for year t , b the adjustment coefficient and U_t a random error.

This equation can be estimated by least squares (L.S.) as follows:

$$P_t - P_{t-1} = bE_t^M - bP_{t-1} + U_t \quad 4.14$$

where bE_t^M is the constant term in simple linear regression. E_t^M can thus be estimated by dividing the constant term by the adjustment coefficient b . The production elasticities for the nine input categories are presented in Table 4.5 in the last row. In this table the elasticity of land is shown to be clearly positive. Equation 4.14

was estimated for each of the nine input groups and the results are also presented in Table 4.5. The F-value of the total regression is also reported for each input.

TABLE 4.5. ELASTICITIES AND ADJUSTMENT COEFFICIENTS OF NINE INPUTS
DERIVED FROM SIMPLE LEAST SQUARES EQUATIONS.
1949/1950 - 1965/1966.

	Fertilizer (X_1)	Labour (X_2)	All farm machinery (X_3)	Land (X_4)	Livestock (X_5)	Fuel & repair charges of all farm machinery (X_6)	Farm dips and sprays (X_7)	Fixed improvements (X_8)	Other operating inputs (X_9)
Constant term	.0026	.1026	.0763	.1103	.0587	.0304	.0038	.1194	.010
b	.0417	.6517	.6032	.7837	.9279	.3567	.1196	1.0804	.211
F value of total regression	9.34	1.70	6.24	9.32	12.18	3.21	.61	18.63	1.54
E_t^*	.0618	.1574	.1265	.1408	.0633	.0852	.0319	.1105	.048

Because E_t^* is estimated on a relatively short period (17 years) it can be assumed that E_t^* did not change very much. For a longer period it may be more realistic to break the period down into more technological homogeneous parts.

4.1.2.2. Estimation of elasticities by autoregressive least squares (A.L.S.).

In estimating equation 4.14 it was explicitly assumed that the error U_t is random ($E(U_t) = 0$). The error term in equation 4.14 tends to be autocorrelated when estimated by least squares as in section 4.1.2.1, resulting in biased and inefficient parameter

estimates.

If serial correlation exists the model can be specified as follows:

$$P_t - P_{t-1} = b(E_t^M - P_{t-1}) + U_t \quad 4.15$$

In a first order autocorrelated scheme $U_t = \beta U_{t-1} + \epsilon_t$ where β is the autocorrelated coefficient and ϵ_t is normally distributed. This is the simplest form of scheme.

The coefficient β can now be estimated by autoregressive least squares.

Multiply 4.15 by β and lag the equation as in 4.16.

$$\beta P_{t-1} - \beta P_{t-2} = b\beta E_{t-1}^M - b\beta P_{t-2} + \beta U_{t-1} \quad 4.16$$

Solve βU_{t-1} in equation 4.16. Then solve U_t using the first order autocorrelated scheme $U_t = \beta U_{t-1} + \epsilon_t$. Having found the value of U_t substitute this in equation 4.15 and rearrange terms to get equation 4.17.

$$P_t = b[E_t^M - \beta E_{t-1}^M] + (1 - b + \beta)P_{t-1} + (b - 1)\beta P_{t-2} + \epsilon_t \quad 4.17$$

If $\beta = 0$ then equation 4.17 reduces to the least squares model.

The autocorrelated and adjustment coefficients can be estimated from the partial coefficients of P_{t-1} and P_{t-2} .

The elasticity estimate can be estimated from the constant term

$$b[E_t^M - \beta E_{t-1}^M] = \text{constant term} \quad 4.18$$

$$b[1 - \beta]E_t^M = \text{constant term} \quad 4.19$$

E_{t-1}^M is approximated by E_t^M

$$E_t^M = \frac{\text{constant term}}{b(1 - \beta)} \quad 4.20$$

Equation 4.17 was fitted for all nine inputs in a log transformation and in an original form to see whether it could improve the least squares fit as determined by an F test. In all the cases where

the least square's fits were unsatisfactory a substantial improvement was obtained by the autoregressive least square (A.L.S.). For example the F value of regression improved for farm feeds, dips and sprays from a very low .61 to a high 26.04 and for other operating inputs from 1.54 to 16.29. (Compare the F values for corresponding inputs in Tables 4.5 and 4.6.).

TABLE 4.6. ELASTICITIES AND ADJUSTMENT COEFFICIENTS OF INPUTS DERIVED FROM AUTOREGRESSIVE LEAST SQUARES (A.L.S.). DATA IN ORIGINAL FORM. 1949/50 - 1965/66.

Parameters	Labour (X_2)	Fuel & repair charges for all farm machinery (X_6)	Farm feeds, dips and sprays (X_7)	Other operating inputs (X_9)
$b(1 - \beta)E_t^M$	.0056	.0298	.0030	.0106
$(1 - b + \beta)$	.4639 ($t = 2.0$)	.3438 ($t = 1.48$)	.6025 ($t = 3.08$)	.5227 ($t = 2.52$)
$(b - 1)\beta$	.4858 ($t = 2.18$)	.3202 ($t = 1.41$)	.3255 ($t = 1.55$)	.2775 ($t = 1.33$)
F_{value}	4.93	6.01	26.04	16.29
β	-.503	-.420	-.336	-.327
b	.034	.238	.031	.150
E_t^M	.3316	.0625	.0731	.0530

The A.L.S. were further used only when the value of β was significant. The A.L.S. equation was fitted in logarithms and original values but the latter was chosen in all cases on the basis of higher R^2 and more realistic parameters.

The labour and farm feeds, dips and sprays elasticities of the

A.L.S. model are double those of the LS model. The other two elasticities of Table 4.6 show a moderate change on that of Table 4.5. When the four elasticities of Table 4.6 were used instead of the corresponding four of Table 4.5, the returns to scale of all nine inputs came to 1.02.

The adjustment rates in Table 4.6 indicate a very slow movement towards equilibrium. In equation 4.11 equilibrium is defined as the condition when the marginal product of the resource is equal to the factor product price ratio.

4.1.3. Evaluation of factor shares and cross-sectional elasticities.

The method of estimating elasticities by factor shares does not take into account interactions of production factors as would be the case when all factors are fitted in one production function. As was pointed out before, the problem of multicollinearity does not exist in the factor shares approach and no theoretical limit is placed on the number of inputs. For the estimation of the parameters of land, livestock, all farm machinery, and fixed improvements a factor (interest and depreciation) was applied to convert all these inputs to flows. In a direct production function (like Cobb-Douglas), the magnitude of this conversion factor does not influence the magnitude of the elasticities. On the other hand in the factor share's method, these elasticities are directly influenced by the conversion factor chosen by the researcher.

Bearing in mind the pros and cons of both procedures it was decided to construct an aggregate production function (Equation 4.21) on the basis of results from the two studies where the variables are explained in Table 4.5 and K_1 is the constant term

$$Y = K_1 X_1^{.062} X_2^{.230} X_3^{.127} X_4^{.080} X_5^{.230} X_6^{.063} X_7^{.073} X_8^{.111} X_9^{.053}$$

4.21

No sophisticated weighting scheme was used to derive the elasticities, depicted in equation 4.21, from results of both methods. Elasticities were chosen from the cross-sectional production function models and from tables 4.5 and 4.6. In cases where elasticities were estimated using both procedures an approximate average elasticity was taken depending on the reliability of individual estimates.

4.1.4. Elasticities of substitution between factors

The elasticity of substitution between X_1 and X_2 is defined here as the percentage change in X_1 associated with a 1% change in X_2 with output unchanged (69, pp. 144-145) (76, p. 54). This definition differs from that of Allen (2, p. 341).

$$E2.1 = \frac{dX_1}{dX_2} \cdot \frac{X_2}{X_1} = \frac{\partial Y / \partial X_2}{\partial Y / \partial X_1} \frac{X_2}{X_1} = - \frac{b_2}{b_1} \quad 4.22$$

The elasticities of substitution between the nine inputs are presented in Table 4.7 where the column elasticities are divided by the row elasticities.

TABLE 4.7.

TABLE 4.7. ELASTICITIES OF SUBSTITUTION BETWEEN NINE INPUTS.

	Ferti- lizer (X_1)	labour (X_2)	All farm machinery (X_3)	Land (X_4)	live- stock (X_5)	Fuel & repair charges of all farm machinery (X_6)	Farm feeds dips and sprays (X_7)	Fixed im- prove- ments (X_8)	Other oper- ating inputs (X_9)
X_1	-1								
X_2	-.270	-1							
X_3	-.488	-1.811	-1						
X_4	-.775	-2.875	-1.584	-1					
X_5	-.270	-1.000	-.552	-.348	-1				
X_6	-.984	-3.651	-2.016	-1.270	-3.651	-1			
X_7	-.849	-3.151	-1.740	-1.095	-3.151	-.863	-1		
X_8	-.559	-2.076	-1.144	-.721	-2.076	-.568	-.658	-1	
X_9	-1.169	-4.340	-2.396	-1.509	-4.340	-1.189	-1.377	-2.095	-1

According to Table 4.7, a 1% increase (decrease) in labour will result in a 1.81% decrease (increase) in machinery given that production is unaltered. The elasticities of substitution of labour with respect to the other resources are high indicating that a greater than proportional increase of these resources is necessary to release a given percentage of farm labour, with production unchanged. The following inputs have important substitution relationships with labour: land, all farm machinery and operating inputs.

Using cost data for the five year period with mid-year as 1960, the cost of the resources may be illustrated. R1.38 m worth of farm labour can be released by an additional investment in machinery of

R9.25 m. According to the coefficients the same reduction in farm labour could also be effected by an additional investment in fertilizers of R1.22 m. A 1% increase in fertilizer use could also release .76% of farm land. This implies that additional purchases of fertilizer by R.33 m could release R19.12 m worth of agricultural land. The substitution really exists between fertilizer use and the approximately 10 million hectares of arable land and land under permanent crops. The marginal rate of substitution of fertilizer for land can be expected to decrease rapidly in future as a result of diminishing returns from greater applications of fertilizer. It can thus, from a pure production function context, also be expected that fertilizer alone will not have numerical substitution rates for land as large as it had over the past years. Less land in the future will thus be substituted by the same amount of fertilizer than at present.

These substitution relationships between labour, land and fertilizer are important because fertilizer is subsidized by the State. The effect of an increase in one resource on other resources depends in practice on the factor-factor relationships. Heady (69, p. 194) distinguishes between three relationships; economic substitutes, economic complements and technical complements. A subsidy of fertilizer has a stimulating effect on production in which case the estimated amount of other resources is not released. Fertilizer and farm machinery are expected to be of a technical complementary nature and fertilizer subsidies may lead to greater mechanization.

A 1% increase in machinery is estimated to release 1.58% of agricultural land from production, assuming production remains constant. Thus an additional investment of R5.11 m in farm machinery could release R39.06 m worth of agricultural land. The level of production

also remains unchanged if land is reduced by 1% and livestock increased by .35%. Farm leaders in South Africa have, however, constantly warned against overstocking in certain areas (122, p. 3) (33, p.9) (62, p.10) (95, pp. 5,10). In these areas livestock and land must be seen as technical complements. Livestock and farm feeds, dips and sprays are also of a complementary nature.

Another relationship of interest is between land and fixed improvements. One percent of agricultural land can be released by increasing investment in improvements by .72%. Thus an additional R6.72 m investment in improvements is expected to release R24.72 m worth of farm land. More investment in fencing and irrigation improvements come to mind here. By farming the remainder of the land more intensively output can be maintained.

The marginal products of the various resources are also indicators of the expected change of factor use (section 4.1.7.1.). In sections 4.1.7.2 and 4.1.7.3 the substitution between resources is further illustrated by showing that the same output can be produced when less of certain resources are used and more of others.

4.1.5. Elasticity of demand and supply of inputs

4.1.5.1. Theory on derived factor demand

In the simplest form the demand for a factor can be specified in terms of the factor and product price. The percentage change in use of a particular input corresponding to a 1% change in factor price is called "the elasticity of demand", and corresponding to a 1% change in product (or competing factor) price is called "the cross elasticity of demand".

Under the profit maximizing principle, each input is used until the marginal value product equals the marginal factor cost of

the input. This means that with a two factor Cobb-Douglas production function,

$$Y = aX_1^{b_1} X_2^{b_2} \quad 4.23$$

where X_2 is held constant, X_1 is employed until

$$\frac{\partial Y}{\partial X_1} = ab_1 X_1^{b_1-1} X_2^{b_2} = \frac{P_{X_1}}{P_Y} \quad 4.24$$

the demand function for X_1 , keeping X_2 constant is

$$X_1 = \left[ab_1 X_2^{b_2} P_Y P_{X_1}^{-1} \right]^{1/1-b_1} \quad 4.25$$

The cross-elasticity of demand is $1/1-b_1$ and the direct elasticity of demand is $\frac{-1}{1-b_1}$, so only one is usually given.

Edwards, (34) using a demand function similar to equation 4.25, says that the Cobb-Douglas production function implicitly assumes an elastic demand for all factors of production under conditions of diminishing returns. For example, using the demand elasticity for the first input $\frac{-1}{1-b_1}$ and substituting different values for b_1 then

$$0 < b < 1 \Rightarrow -\infty < \text{Elasticity of factor demand} < -1.$$

Under diminishing returns the demand for inputs will numerically always be greater than one.

This conclusion is correct for an individual firm with a perfectly elastic demand for products but does not hold for the industry unless its demand is also perfectly elastic. This will be shown by using the two factor production function of equation 4.23.

The marginal value product function for each input is derived from equation 4.21.

$$P_{X_1} = ab_1 X_1^{b_1-1} X_2^{b_2} P_Y \quad 4.26$$

$$P_{X_2} = ab_2 X_1^{b_1} X_2^{b_2-1} P_Y \quad 4.27$$

where P_{X_1} and P_{X_2} are prices of X_1 and X_2 respectively and P_Y is the product price.

The supply functions of inputs may be specified as:

$$X_1 = K_1 P_{X_1}^{\alpha_1} \quad 4.28$$

$$X_2 = K_2 P_{X_2}^{\alpha_2} \quad 4.29$$

where α_i 's are the supply elasticities for the inputs.

The product demand function is

$$Y = (P_Y)^{-e} \quad \text{where } e = \text{elasticity of product demand.} \quad 4.30$$

Equations 4.23, 4.26, 4.27, 4.28, 4.29 and 4.30 comprise a complete system determining unique values for Y , P_Y , X_1 , X_2 , P_{X_1} and P_{X_2} . By keeping other input quantities constant or other prices constant this closed system is unlocked.

(1) Other input quantities constant

Determining the elasticity of demand for the first input when other input quantities are constant, equations 4.28 and 4.29 can be dropped because any desired amount of X_1 is assumed and X_2 is fixed.

Remembering that Y , P_Y , X_1 and P_{X_2} are endogenous variables and P_{X_1} and X_2 are considered exogenous, then the reduced form demand equation for the first input can be computed as follows:

$$\begin{aligned} P_{X_1} &= a b_1 X_1^{b_1-1} X_2^{b_2} P_Y = a b_1 X_1^{b_1-1} X_2^{b_2} Y^{1/e} \\ &= a b_1 X_1^{b_1-1} X_2^{b_2} a^{1/e} X_1^{b_1/e} X_2^{b_2/e} = K X_1^{b_1(1+1/e)-1} X_2^{b_2(1+1/e)} \end{aligned}$$

The constant K is not of any interest here.

The elasticity of demand for the first input when other inputs are held constant is:

$$\epsilon_{11} = \frac{1}{b_1[1 + 1/e] - 1} \quad 4.31$$

In Table 4.8 different factor demand elasticities are derived for certain product demand elasticities from equation 4.31.

TABLE 4.8. RELATIONSHIP BETWEEN THE ELASTICITY OF DEMAND FOR A PRODUCTION FACTOR AND THE ELASTICITY OF DEMAND FOR THE PRODUCT WHEN OTHER INPUT QUANTITIES ARE KEPT CONSTANT (HYPOTHETICAL DATA).

Product demand elasticity	Factor demand elasticity	
	$b = b_1$	$b_1 = \frac{1}{2}$
0	0	0
-0.5	$(-b_1 - 1)^{-1}$	$-\frac{2}{3}$
-1	-1	-1
-5	$(-0.8b_1 - 1)^{-1}$	$-1\frac{2}{3}$
$-\infty$	$(b_1 - 1)^{-1}$	-2

From Table 4.8 it can be seen that the demand for one input, when quantities of other inputs are held constant, is elastic, ~~of~~ unit elasticity or inelastic as the demand for the output is elastic, ~~of~~ unit elasticity or inelastic. Also if the demand for the product is perfectly elastic, then the factor demand reduces to $\epsilon_{11} = \frac{1}{b_1 - 1}$ which is the same elasticity as that indicated by equation 4.25 when the product demand was ignored.

Factor demand elasticities can also be determined when other input prices are kept constant.

(ii) Other input prices constant

When other input prices are constant in deriving product demand, equations 4.26 and 4.29 can again be ignored because the inputs are

assumed to be available in sufficient quantities. P_{X_1} and P_{X_2} are exogenous variables and Y , P_Y , X_1 and X_2 are endogenous variables.

The four structural equations can now be used to obtain the desired reduced form equation representing the demand function for the first input

$$X_1 = K P_{X_1}^{b_1(1+e)-1} P_{X_2}^{b_2(e+1)} \quad 4.32$$

This can be done by substitution. Ignore constant terms for convenience and take logarithms of structural equations

$$\ln Y = b_1 \ln X_1 + b_2 \ln X_2 \quad (a)$$

$$\ln P_{X_1} = (b_1 - 1) \ln X_1 + b_2 \ln X_2 + \ln P_Y \quad (b)$$

$$\ln P_{X_2} = b_1 \ln X_1 + (b_2 - 1) \ln X_2 + \ln P_Y \quad (c)$$

$$\ln P_Y = f \ln Y \text{ where } f = \frac{1}{e} \quad (d)$$

$$\therefore \ln P_Y = f \ln Y = f b_1 \ln X_1 + f b_2 \ln X_2 \quad (e)$$

$$\text{But } (b - c) : \ln P_{X_1} - \ln P_{X_2} = -\ln X_1 + \ln X_2 \quad (f)$$

Substitute (e) into (b)

$$\begin{aligned} \ln P_{X_1} &= (b_1 - 1) \ln X_1 + b_2 \ln X_2 + f b_1 \ln X_1 + f b_2 \ln X_2 \\ &= (b_1 + f b_1 - 1) \ln X_1 + (b_2 + f b_2) \ln X_2 \\ &= (b_1 + f b_1 - 1) \ln X_1 + (b_2 + f b_2) \ln P_1 + (b_2 + f b_2) \ln X_2 \\ &\quad - (b_2 + f b_2) \ln P_2 \quad \text{by substituting (f)} \end{aligned}$$

$$\begin{aligned} \therefore \ln X_1 &= (b_2 + f b_2) / (b_1 + f b_1 + b_2 + f b_2 - 1) \ln P_{X_2} \\ &\quad + (1 - b_2 - f b_2) / (b_1 + f b_1 + b_2 + f b_2 - 1) \ln P_{X_1} \end{aligned}$$

By assuming constant returns to scale ($b_1 + b_2 = 1$) the former equation can be further simplified.

$$\begin{aligned}
 X_1 &= KP_{X_1}^{(b_1(1+f)/f)-1} P_{X_2}^{b_2(1+f)/f} \\
 &= KP_{X_1}^{b_1(1+e)-1} P_{X_2}^{b_2(e+1)}.
 \end{aligned}$$

Table 4.9 shows how the factor demand elasticities vary for given product demand elasticities when input prices are kept constant.

TABLE 4.9. RELATIONSHIP BETWEEN THE ELASTICITY OF DEMAND OF A PRODUCTION FACTOR AND THE ELASTICITY OF DEMAND FOR THE PRODUCT WHEN OTHER INPUT PRICES ARE KEPT CONSTANT. (HYPOTHETICAL DATA).

Product demand elasticity	Factor demand elasticity	
	$b_1 = b_1$	$b_1 = \frac{1}{2}$
0	$b_1 - 1$	$-\frac{1}{2}$
-0.5	$\frac{1}{2} b_1 - 1$	$-\frac{3}{4}$
-1	-1	-1
-5	$-4b_1 - 1$	-3
$-\infty$	$-\infty$	$-\infty$

As in the previous case, the factor demand is elastic of unit elasticity or inelastic respectively as the product demand is elastic, of unit elasticity or inelastic.

When Table 4.9 is compared with Table 4.8 it can be seen that the factor demand is more elastic when prices of inputs are kept constant than when input quantities are kept constant (excluding the point of unit elasticity).

A more realistic approach is not to put any restriction on the system but because input supply elasticities were not known beforehand,

this was not done.*

4.1.5.2. Practical implications

Elasticities of demand for factors in South African agriculture can now be computed if and when other input quantities are kept constant and equilibrium** in the product market is assumed.

TABLE 4.10. FACTOR DEMAND ELASTICITIES WHEN THE PRODUCT DEMAND ELASTICITY IS PERMITTED TO VARY AND OTHER INPUT QUANTITIES ARE KEPT CONSTANT.

Elasticity of demand for product	Factor demand elasticities								
	Fertilizer (x_1)	Labour (x_2)	All farm machinery (x_3)	Land (x_4)	Livestock (x_5)	Fuel & repair charges of all farm machinery (x_6)	Farm feeds dips & sprays (x_7)	Fixed improvements (x_8)	Other operating inputs (x_9)
0	.000	.000	.000	.000	.000	.000	.000	.000	.000
- .25	-.843	-.592	-.725	-.806	-.592	-.841	-.812	-.750	-.863
- .50	-.942	-.813	-.887	-.926	-.813	-.941	-.932	-.900	-.950
- .75	-.979	-.929	-.960	-.974	-.929	-.979	-.977	-.964	-.982
-1.00	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000
-1.25	-1.012	-1.048	-1.026	-1.016	-1.048	-1.013	-1.015	-1.022	-1.011
- ∞	-1.066	-1.299	-1.145	-1.089	-1.299	-1.067	-1.079	-1.125	-1.056

When a product demand elasticity of -.5 is assumed then according to Table 4.10 a 1% decrease in fertilizer price will increase fertilizer

* Ideas expressed under items (i) and (ii) are based on the work of Buse (17), Friedman (42) and especially Brandow (12). Equations 4.26 - 4.32 were borrowed from the latter source, but because of its importance in the interpretation of empirical results it was felt necessary

** This assumption was necessary to derive equation 4.31.

consumption by .942% given that other input quantities are kept constant. However, when the product price is considered as exogenous then a 1% increase in product price will increase fertilizer consumption by 1.066%. When product demand elasticity is $-.5^*$ then a 1% increase in the wage rate will reduce labour by .813%. When the product demand is elastic, a 1% increase in product price will increase labour by 1.299%. The other elasticities can be interpreted in the same fashion.

The elasticity of product supply measures the percentage change in output associated with a 1% change in product price (137).

$$\begin{aligned} \text{The elasticity of product supply} &= \frac{dY}{dP_Y} \cdot \frac{P_Y}{Y} \\ &= \left(\frac{dX_i}{dP_Y} \cdot \frac{P_Y}{X_i} \right) \left(\frac{\partial Y}{\partial X_i} \cdot \frac{X_i}{Y} \right) \\ &= \left(\text{Cross elasticity of input demand} \right) \left(\text{Production elasticity of input} \right) = \frac{b_1}{1 - b_1} = -1 + \frac{1}{1 - b_1} \end{aligned}$$

4.33

As equation 4.33 is derived from equation 4.25 it is assumed that factor demand is perfectly elastic. Product supply elasticities are derived from equation 4.33 and presented in Table 4.11. The elasticities indicate the response in product supply caused by a change in a particular input which is reflected via a change in product price. All other inputs are held constant. Because of this assumption the supply elasticities are called "simple". The supply elasticity does

* The elasticity of the demand for agricultural products has been estimated for the U.S.A. as approximately $-.25$ (137, p.623) (37). South African Agriculture however faces a more elastic foreign demand than the U.S.A. From this it may be deduced that the elasticity of demand for agricultural products in South Africa is more elastic than that of the U.S.A.

TABLE 4.11. SIMPLE ELASTICITIES OF PRODUCT SUPPLY FOR NINE INPUTS.
1949/1950 - 1965/1966.

Ferti- lizer (x_1)	Labour (x_2)	All farm machi- nery (x_3)	Land (x_4)	Liv- stock (x_5)	Fuel & repair charges of all farm machi- nery (x_6)	Farm feeds dips & sprays (x_7)	Fixed im- prove- ments (x_8)	Other oper- ating inputs (x_9)
.066	.299	.145	.089	.299	.067	.079	.125	.056

not mean that the only response to a change in product price would be to change one input, but to indicate if this were the sole change. It is further assumed that the supply of inputs is perfectly elastic. This assumption is violated in the case of real estate.

In the long run all inputs are variable, but in the short run certain inputs are fixed. The inputs are classified in Table 4.12 in three groups with respect to time required for adjustment: cash operating inputs x_1 , x_6 , x_7 and x_9 , and durable capital x_3 , x_5 and x_8 . It was considered possible to vary the labour input in the long run. Supply elasticities were estimated for each length of run. An increase of 1% of product price will increase production in the short run by .34%. This will be possible due to increased use of fertilizer, fuel and repair charges of farm machinery, farm feeds, dips and sprays and other operating inputs. In the intermediate run, farm machinery, livestock and fixed improvements will become variable and production will increase by approximately 2.56% in response to 1% increase in the price of the product. Labour will become variable in the long run and production will further respond. The Cobb-Douglas derived supply elasticities are the maximum potential response and

TABLE 4.12. SUPPLY ELASTICITIES* FOR THREE LENGTHS OF RUN.
1949/1950 - 1965/1966.

Length of run	Inputs variable	Supply elasticity
Short	X_1, X_6, X_7, X_9	0.335
Intermediate	X_3, X_5, X_8 (plus above)	2.555
Long	X_2 (plus above)	18.608

overestimate the true effect. Resources are more easily adjusted among agricultural products than between agricultural and non-agricultural products. It can thus be expected that the supply of individual crops is more elastic than the aggregate supply (135).

The writer was going through the draft of this thesis when he came across an article recently (February, 1969) published in the American Journal of Agricultural Economics by Wipf and Bowden (148) on the "Reliability of Supply equations derived from production functions". They found the elasticities and output predictions to be over-sensitive to changes in the length of run. This also appears to be the case in this study with the distinct differences in elasticities between lengths of run. They concluded that the logarithmic function may lead to somewhat erroneous predictions if the sum of the production elasticities is larger than one-half. The writers based their findings on estimates obtained from different production functions. These shortcomings of the results presented in this study were expected but were not considered important enough to outweigh the advantage of being able to distinguish between different lengths of run. Bearing this in mind it may still be concluded that the supply of agricultural products is not completely inelastic.

* Elasticity of supply = $\frac{\sum b_i}{1 - \sum b_i}$

4.1.6. Value of the marginal product and demand curves of a factor (labour) for the Agricultural Industry under competitive conditions.

The demand curve for a factor is often loosely described by the value of the marginal product of the factor. This is strictly only correct when other factors cannot be increased or decreased. In this case the only adjustment a firm can make in response to a price change of the factor is to vary the quantity of the factor employed accordingly.

If the price of a factor is decreased, more of that factor will be employed. Marginal products of complementary resources will increase and that of substitute resources will decrease. If the former effect dominates and other resources are permitted to increase then the marginal productivity of the original factor will in turn increase and so the employment of this factor.

In a nutshell, the marginal value product curve is derived for fixed quantities of other factors, but the demand curve is derived for fixed prices of variable factors and fixed quantities of fixed factors. In both cases the demand curve for the product is assumed to be perfectly elastic.

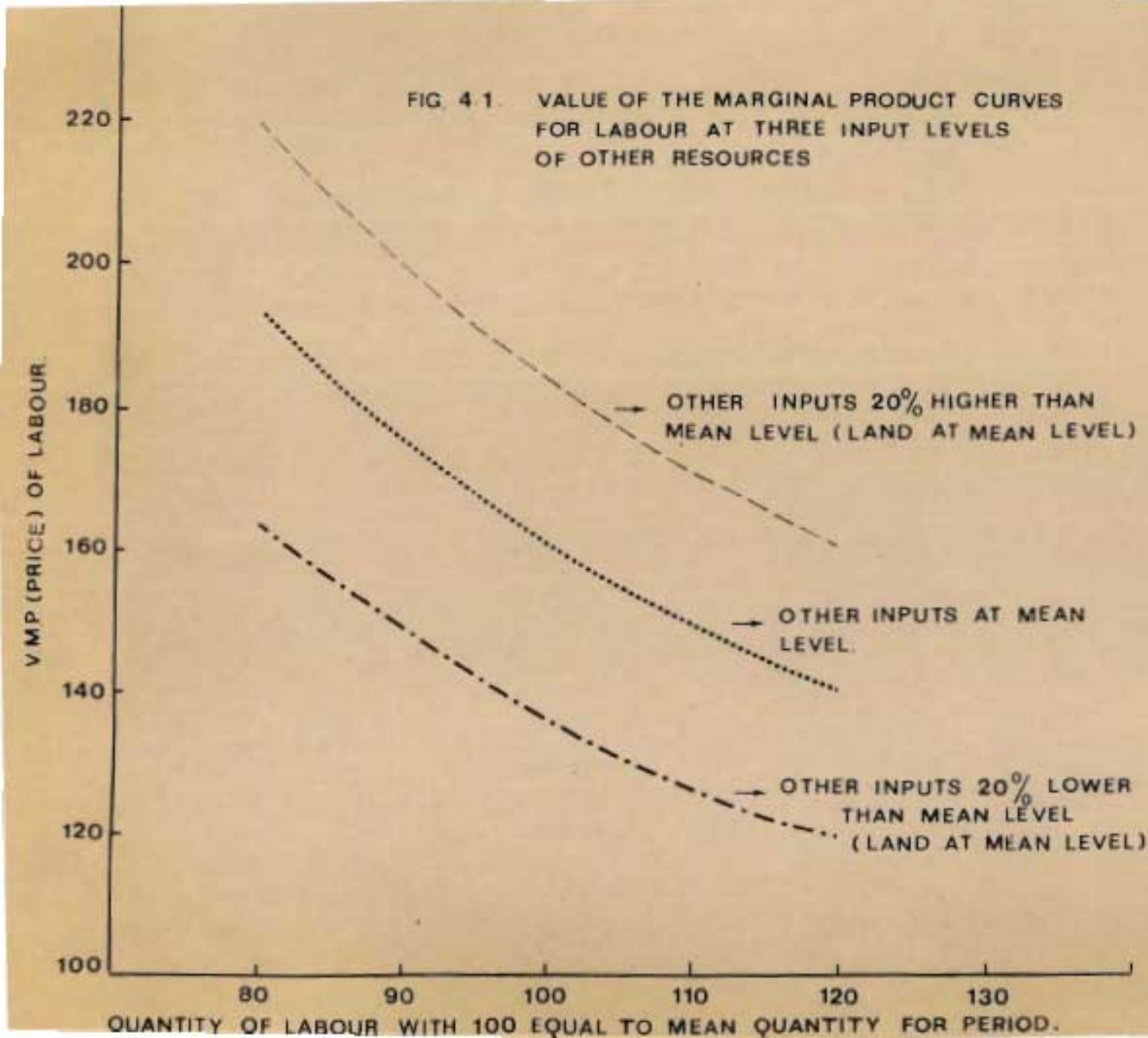
The value of the marginal product (V.M.P.) of labour is derived from the production function for S.A. when all other inputs are kept constant at their mean (geometric) levels. The relationship is, strictly speaking, invalid because for the industry the other resources are variable and the product demand is not perfectly elastic. The schedule in Fig. 4.1 shows the extent to which an increase in the wage rate* or V.M.P. will cause a reduction in the labour force. The

* The wage rate is equal to the value of the marginal product of labour only under competitive and equilibrium conditions. The productivity of labour in this study is estimated at 60% higher than the agricultural wage rate.

FIG. 4.1. VALUE OF THE MARGINAL PRODUCT CURVES FOR LABOUR AT THREE INPUT LEVELS OF OTHER RESOURCES

Lab No.	MP ₁	MP ₂	MP ₃
80	164	193	220
90	150	176	201
100	138	162	186
110	128	151	172
120	120	141	161

MP₂ other inputs at mean level.
MP₁ and MP₃ other inputs at 20% lower and higher respectively than mean. (land fixed)



quantity of labour in Fig. 4.1 is in terms of an index with the mean quantity of labour as the base. (= 100).

All other inputs were also increased and decreased by an arbitrary 20% except land. Land was kept at the mean level as it is not feasible to increase this factor. The V.M.P. schedule of labour moves to the right with increased employment of other resources with the consequence that the same amount of labour can command a higher wage. For instance, the V.M.P. of labour at the mean level increased from 160 to 185 when other factors were increased by 20% and land was kept constant. It was stated earlier that product demand is assumed to be elastic. In practice, however, the increased employment of resources in the Agricultural Industry will have a general depressing effect on product prices because of increased production. The result will be that the V.M.P. schedule will not shift to the same extent as indicated in Fig. 4.1.

The effect of a reduction in other resources on the V.M.P. of labour is also shown in Fig. 4.1. The demand curve for labour is estimated in a separate section (Chapter 5). Because quantities of variable resources are not limited in the construction of the demand function, the latter is more elastic than the V.M.P. curves.

The effect of the size of the labour force and the level of other resources on the wage rate is extremely important from a policy point of view, because it shows how the V.M.P. of labour and thus wages can be increased through a reduction of the labour force in agriculture and greater mechanisation. From this relationship it is possible to determine by how much labour in agriculture must decrease to bring farm and industrial wages on a par.

Value of marginal product curves for the other resources can be derived in a similar fashion. This, however, was not done because the direction of change can be shown to be the same and because of limited space.

4.1.7. Reallocation of resources in Agriculture

For determining optimum resource allocation, the constant term in equation 4.21 has still to be estimated.

This constant term can be estimated if $X_1^{b_1} \cdot X_2^{b_2} \dots X_9^{b_9}$ are taken as one variable, X . The different values for X_i and b_i are substituted to get an X value for each of the 17 years. For this purpose all the variables were deflated by their corresponding price indexes except land which was deflated by the wholesale price index and fertilizer which was expressed in thousand tons of fertilizer.

The equation $Y = kX + u$ was estimated by least squares, forcing a zero intercept where $\hat{k} = \sum XY / \sum X^2$. The constant term was estimated as 9.196 and the production function is thus completely specified.

4.1.7.1. Marginal products

The marginal product for the i^{th} resource was calculated by using the formula:

$$\text{Marginal Product} = \frac{\partial Y}{\partial X_i} = b_1 X_1^{b_1-1} \dots X_i^{b_i-1} \dots X_n = b_i \frac{Y}{X_i} \quad 4.34$$

The most reliable estimate of marginal productivity is obtained when X_i is taken at its geometric mean and Y is taken as the estimated level of output when each input is held at its geometric mean (73, p. 231).

TABLE 4.13. MARGINAL PRODUCTS OF RESOURCES AT MEAN LEVELS. (INCREASE IN OUTPUT PER 100 INCREASE IN INPUT)*

Ferti- lizer (x_1)	Labour (x_2)	All farm machi- nery (x_3)	Land (x_4)	Live- stock (x_5)	Fuel & repair charges of all farm machi- nery (x_6)	Farm feeds dips & sprays (x_7)	Fixed im- prove- ments (x_8)	Other oper- ating inputs (x_9)
113	160	112	59	329	81	245	96	101

According to Table 4.13 the marginal product of land is very low while the marginal products of livestock, farm feeds, dips and sprays and labour are very high. This shows that an expansion of the livestock enterprise should increase profits or reduce cost at a fixed level of output when it substitutes for other inputs. Of the remaining inputs, fertilizer, all farm machinery and other operating inputs have marginal products greater than 100 and fuel and repair charges of farm machinery and fixed improvements have marginal products less than 100. The marginal product of all farm machinery was found to be greater than 100 and for fuel and repair charges of farm machinery to be lower than 100. No explanation could be advanced for this and it appears to be a contradictory result. The great percentage of fuel and repair charges spent on lorries and cars may be a partial explanation of this result.

4.1.7.2. Minimum cost input levels

The cost function can be specified as

$C = \sum p_i X_i$ where cost is the sum of input quantities, times their respective prices. Prices of all inputs except fertilizer will be assumed

* Confidence intervals for the marginal products cannot be given because the elasticities are estimated by factor shares.

as R1 because these inputs are measured in terms of value. The price of fertilizer was taken as R190 per ton as fertilizer was measured in tons of pure plant nutrients.*

Costs can now be minimized for a predetermined output by using a Lagrange multiplier (λ).

$$C^* = \sum P_i X_i + \lambda \left[Y^* - aX_1^{b_1} \dots X_n^{b_n} \right] \quad 4.35$$

Costs can be minimized by equating the partial derivations of all the unknowns to zero and solving the system simultaneously. The asterisk is an indication that production (Y) is predetermined and does not refer to a footnote.

$$\partial C^* / \partial X_1 = P_1 - \lambda (9.196) (.062) X_1^{-.938} X_2^{.230} \dots X_9^{.053} = 0$$

$$\partial C^* / \partial X_2 = P_2 - \lambda (9.196) (.230) X_1^{.062} X_2^{-.770} X_3^{.127} \dots X_9^{.053} = 0$$

$$\partial C^* / \partial X_3 = P_3 - \lambda (9.196) (.127) X_1^{.062} X_2^{.230} X_3^{-.873} \dots X_9^{.053} = 0$$

$$\partial C^* / \partial X_4 = P_4 - \lambda (9.196) (.080) X_1^{.062} \dots X_3^{.127} X_4^{-.920} \dots X_9^{.053} = 0$$

$$\partial C^* / \partial X_5 = P_5 - \lambda (9.196) (.230) X_1^{.062} \dots X_4^{.080} X_5^{-.770} \dots X_9^{.053} = 0$$

$$\partial C^* / \partial X_6 = P_6 - \lambda (9.196) (.063) X_1^{.062} \dots X_5^{.230} X_6^{-.937} \dots X_9^{.053} = 0$$

$$\partial C^* / \partial X_7 = P_7 - \lambda (9.196) (.073) X_1^{.062} \dots X_6^{.063} X_7^{-.927} \dots X_9^{.053} = 0$$

$$\partial C^* / \partial X_8 = P_8 - \lambda (9.196) (.111) X_1^{.062} \dots X_7^{.073} X_8^{-.889} \dots X_9^{.053} = 0$$

$$\partial C^* / \partial X_9 = P_9 - \lambda (9.196) (.053) X_1^{.062} \dots X_8^{.111} X_9^{-.947} = 0$$

$$\partial C^* / \partial \lambda = Y^* - 9.196 X_1^{.062} \dots X_9^{.053} = 0$$

4.36

* For analysis purposes fertilizer consumption was coded to the nearest thousand tons and all other inputs to the nearest million rand at constant prices. The fertilizer price was consequently coded as R0.190.

This system can be solved by taking logarithms of the 10 simultaneous linear equations and inverting the corresponding matrix. The following short cut, however, was used. From the first nine equations the values of the X_i 's were determined as $X_i = \frac{\lambda(b_i)Y}{P_i}$ and these values were then substituted into the last equation. Because Y^* is predetermined, the value of the Lagrange multiplier (λ) can be solved from the last equation. The minimum cost levels can then be determined.

The first column in Table 4.14 shows the average cost figures for the period under study.

TABLE 4.14. ESTIMATED MINIMUM COST LEVELS OF INPUTS FOR THE AVERAGE OUTPUT OF THE PERIOD 1949/1950 - 1965/1966.*

Variables		Actual average cost	Minimum cost when all inputs are variable	Minimum cost when labour, livestock and farm feeds, dips & spray are predetermined
		Rm	Rm	Rm
Fertilizer	(X_1)	28.4	21.5	30.7
Labour	(X_2)	74.7	79.9	74.7
All farm machinery	(X_3)	58.9	44.1	63.1
Land	(X_4)	69.8	27.8	39.8
Livestock	(X_5)	36.2	79.9	45.0
Fuel and repair charges of machinery	(X_6)	40.5	21.9	31.3
Farm feeds, dips & sprays	(X_7)	15.5	25.3	19.2
Fixed improvements	(X_8)	60.1	38.5	55.1
Other operating inputs	(X_9)	27.2	18.4	26.3
TOTAL COST		411.3	357.3	385.2
TOTAL OUTPUT		527	527	527

* All costs items are deflated by their respective price indexes except for the value of land which is deflated by the wholesale price index.

The middle column in Table 4.14 indicates the minimum cost levels needed to produce the average output when all inputs are variable. Costs can be reduced from R411.3 m to R357.3 m or by R54.0 m if resources are employed where the value of the marginal products of the resources are equal to their respective prices. This is a cost reduction of 13.1%. The direction of change of inputs is as expected according to their marginal products (Table 4.13). Livestock inputs increased from R36.2 m to R79.9 m and land was reduced from R69.8 m to R27.8 m. As the labour increase in the minimum cost plan is not feasible, it was decided to keep the labour input at the average input level. Labour increase would be feasible if underemployed labour could be transferred from Bantu reserves. The drastic increase in livestock had the effect of increasing the confidence limits for this variable substantially and making it very unreliable. Livestock was thus given an upper limit of R45.0 m or 24% higher than the original value. In accordance with this, the farm feeds, dips and sprays input was fixed at R19.2 m or 24% higher than the original input. These restrictions had the effect of increasing the minimum cost from R357.3 m to R385.2 m which is still 6.4% less than the average cost figure for the period. The reduction of labour and livestock inputs caused the other inputs to increase showing the substitution relationship between the resources.

An increase in the price of labour to that of the non-farm wage rate (opportunity return) can be expected to reduce the optimum labour force. In these calculations the farm wage rate was used. All farm machinery and fertilizers were reduced in the minimum cost plan notwithstanding the fact that marginal products of these factors were more than 100%. This is because of the high marginal products of livestock

and farm feeds, dips and sprays. In the restricted minimum cost plan both fertilizers and machinery were increased. A small amount of disequilibrium existed in the restricted plan with respect to fixed improvements, all farm machinery, fertilizers and other operating inputs.

It is also interesting to note that both fixed improvements and land were reduced in the minimum cost plans, indicating that land is in "oversupply".

4.1.7.3. Optimum resource allocation

Resources are allocated in an optimum way when the marginal costs of resources are equal to one another and equal to the marginal revenue of the product.

$$\text{Thus } \frac{\partial Y}{\partial X_1} = b_1 \frac{Y}{X_1} = \frac{P_1}{P_Y} \text{ or } X_1 = \left(\frac{b_1 Y}{P_1} \right) P_Y \quad 4.37$$

P_Y is taken as R1, as the production is measured in constant rands. The measurement of inputs is explained in section 4.1.7.2.

The values of the X_1 's determined in this way were then substituted in the production function to solve the system. As in the minimum cost case, labour was fixed at the average labour input of the period while livestock, farm feeds, dips and sprays were given upper limits of 24% above the average levels. These restrictions* reduced the optimum output to a considerable extent as these factors were kept at levels where their marginal products were far greater than 100%.

If the optimum plan is compared with the actual plan, it can be seen that costs increased by R8.6 m but output by R38.8 m. Profits consequently increased from R116.7 m to R146.2 m or by 26.4%.

* The unrestricted production function has an unlimited optimum because returns to scale are 1.029.

TABLE 4.15. OPTIMUM ALLOCATION OF RESOURCES WHEN INPUTS OF LABOUR,
LIVESTOCK, FARM FEEDS, DIPS AND SPRAYS WERE PREDETERMINED.
1949/1950-1965/1966.

Variables		Actual average cost	Optimum allocation when X_2 , X_5 and X_7 are predetermined	Marginal products of resources
		Rm	Rm	%
Fertilizer	(X_1)	28.4	35.1	100.0*
Labour	(X_2)	74.7	74.7	174.2
All farm machinery	(X_3)	58.9	71.9	100.0
Land	(X_4)	69.8	45.3	100.0
Livestock	(X_5)	32.2	45.0	289.2
Fuel and repair charges of machinery	(X_6)	40.5	35.6	100.0
Farm feeds, dips and sprays	(X_7)	15.5	19.2	215.1
Fixed improvements	(X_8)	60.1	62.8	100.0
Other operating inputs	(X_9)	27.2	30.0	100.0
TOTAL COST		411.3	419.6	
TOTAL OUTPUT		527.0	565.8	
PROFIT		115.7	146.2	

A fertilizer increase of 24% and a machinery increase of 22% are recommended for optimum allocation. Other inputs were employed at almost equilibrium levels except land which was in "oversupply".

By definition this optimum plan also resembles minimum cost for the particular level of production derived in the model.

* To make comparison possible, the fertilizer input was converted to a value input.

An increase in product price will also increase the optimum production and the demand for inputs. The effect of product price on output is shown in Table 4.16 under equilibrium factor use. The marginal cost of each factor was equated to its marginal revenue and this was substituted into the production function for each of three different levels of P_Y .

TABLE 4.16. SUPPLY OF AGRICULTURAL PRODUCTS

Price Index	Production (Rm)
80	454.2
100	565.8
120	677.2

The prices and production figures in Table 4.16 trace out a supply curve of agricultural products. Input supply except labour, was assumed perfectly elastic. The same restrictions as in the previous section were placed on the livestock associated inputs.

4.2. Regional production functions

Production functions were estimated for the different Agro-economic areas on the basis of 1959/60 census. The input-output data of the aggregate cross-sectional production function were used for this purpose. Magisterial districts were classified into Agro-economic areas with the aid of Agro-economic and magisterial district maps and types of products. In the study an aggregative measure of output was used because records were not available indicating the quantity of each input associated with each output. According to Heady and Dillon (73, p. 227) the distortions caused by output aggregation may be minimized by deriving separate functions for groups of

firms producing the various outputs in approximately the same proportions. In the Agro-economic areas the farmers produce the same products in approximately the same proportions and some of the distortions were minimized by fitting production functions for the individual areas.

A complete model measuring all inputs was tested for the different regions with little success. This was partly due to inter-correlations between the different capital items. The capital production function with labour, land and capital was estimated. The latter function thus indicates nothing about the productivity of particular forms of capital. This model was estimated in a logarithmic and original form.

To get a breakdown of the capital factors, the aggregate cross-sectional production function for South Africa with dummy variables for the different regions was used. The percentage of income from livestock for a particular region was substituted in the function, the dummy variable for the region was set equal to 1, and the other dummies were ignored to get an estimate for each region. For the functions derived in this way, no t -values, R^2 or degrees of freedom are reported.

The returns to scale are also reported in Table 4.17 (A and B). In the original linear functions, the returns to scale are based on elasticities at geometric mean levels. In most cases the returns to scale are close to unity.

Elasticities from tables 4.17 (A and B) are selected and presented in Table 4.18 with the corresponding marginal products. The latter are given as percentages.

TABLE 4.17A. PRODUCTION COEFFICIENTS FOR AGRO-ECONOMIC AREAS IN SOUTH AFRICA WITH t VALUES BETWEEN BRACKETS 1959/1960.

Agro-economic Region	df	R^2	Constant term	X_1 Current expenditure	X_2 Labour	X_3 Machinery tools and implements	X_4 Land	X_5 Livestock	X_6 Percentage income from livestock	(X_1+X_3)	All Capital inputs $(X_1+X_3+X_5)$	Returns to scale
A_L	25	.808	-.49	.326 (1.10)	.115 (.53)	.444 (1.44)	.094 (.39)	.120 (1.12)	-1.076 (.71)			1.098
A_L			-.65		.193		-.035	.346		.431		.935
A_O	28	.638	13.9		.126 (1.11)		.224 (1.61)				.0219 (.81)	.810
A_L	28	.792	-1.72		.066 (.34)		.255 (1.25)				.781 (4.26)	1.102
B_L^*	24	.884	-1.2	.324 (1.51)	.228 (1.71)	.422 (2.13)	.104 (.41)	.039 (.46)	.0065 (2.44)			1.117
B_L			-.69		.173		-.018	.311		.474		.940
B_O	27	.677	-23.6		.226 (1.52)		.274 (1.57)				.0848 (1.95)	1.244
B_L	27	.828	-1.75		.214 (1.48)		.407 (1.71)				.540 (2.12)	1.161
C_L			-.88		.229		-.066	.408		.355		.926
C_O	18	.732	7.9		.859 (3.82)		-.363 (2.50)				.0707 (6.30)	.907
C_L	18	.846	-.47		.317 (1.89)		-1.276 (5.75)				1.677 (8.68)	
D_L			-.98		.264		-.96	.470		.280		.918
E_L			-.92		.235		-.071	.419		.342		.925
E_O	19	.638	47.2		.154 (4.07)		-.017 (.46)				.0103 (1.12)	

* X_6 not transformed to logarithms.

O - Original values.

L - Logarithmic transformation.

TABLE 17P PRODUCTION COEFFICIENTS FOR AGRO-ECONOMIC AREAS IN SOUTH AFRICA WITH t VALUES BETWEEN BRACKETS 1959/1960.

Agro-economic Region	df	R ²	Constant term	X ₁ Current expenditure	X ₂ Labour	X ₃ Machinery tools and implements	X ₄ Land	X ₅ Livestock	X ₆ Percentage income from livestock	(X ₁ +X ₃)	All Capital inputs (X ₁ +X ₃ +X ₅)	Returns to scale
P _L			-.74		.255		-.088	.454		.299		.920
P _O	6	.9952	-92.5		1.107 (2.84)		-.296 (1.66)				.0767 (30.31)	1.396
H _L			-.59		.201		-.042	.360		.414		.933
H _O	18	.859	-119.2		.410 (2.50)		.109 (.39)				.2874 (5.82)	2.129
H _L	18	.903	-1.7		.270 (1.91)		-.093 (.55)				.921 (6.49)	1.098
K _L *	5	.995	-1.3	.066 (.26)	.273 (4.46)	.436 (2.02)	.364 (2.41)		.0082 (3.23)			1.138
K _O	7	.944	-11.8		.278 (2.43)		.096 (.63)				.0774 (4.83)	1.108
K _L			-.81		.171		-.016	.306		.480		.941
M _L	6	.968	-1.9	.772 (3.10)	.432 (1.42)	.099 (.402)	-.316 (1.31)	.193 (2.52)	.076 (.33)			1.180
M _O	9	.897	3.8		.327 (4.36)		-.123 (2.95)				.1042 (4.47)	
H _L			-.72		.204		-.044	.364		.409		.933
M _L	9	.941	-1.6		.171 (1.41)		-.115 (.91)				.998 (5.97)	1.054
S _L	44	.806	-.7		.339 (3.40)	.032 (.307)	.092 (1.32)	.516 (8.31)	-.0055 (2.32)			.979
S _O	46	.843	1.9		.239 (3.05)		.012 (.53)				.0462 (10.78)	
S _L			-.97		.316		-.141	.561		.169		.905
S _L	46	.740	-1.53		.268 (2.66)		.029 (.39)				.748 (6.72)	1.045

* X₆ not transformed to logarithms. O - Original values. L - Logarithmic transformation.

TABLE 4.18. ELASTICITIES AND MARGINAL PRODUCTS OF FACTORS OF PRODUCTION FOR AGRO-ECONOMIC AREAS IN SOUTH AFRICA.

Agro-economic region	Current expenditure X_1		Labour X_2		Machinery tools and implements X_3		Land X_4		Livestock X_5		(X_1+X_3)	
	cp	MP	cp	MP	cp	MP	cp	MP	cp	MP	cp	MP
A	.33	104	.20	107	.44	533	.20	97	.12	690		
B	.32	93	.22	200	.42	496	.30	178	.31	1430		
C	-	-	.30	277	-	-	-.10	-	.41	860	.36	85
D	-	-	.15	154	-	-	.13	62	.47	540	.29	68
E	-	-	.30	172	-	-	-.05	-	.42	700	.35	101
F	-	-	.30	337	-	-	-.15	-	.46	590	.31	165
H	-	-	.40	189	-	-	.00	0	.36	2130	.42	122
K	-	-	.27	216	.40	390	.30	167	.31	1140	.48	103
M	.41	128	.43	243	-	-	-.20	-	.19	862	.42	102
S	-	-	.31	253	-	-	.09	27	.52	590	.18	39

The MP of labour is more than 100%. This may be because labour is priced at its farm wage rate and not at its opportunity return. It is well known that non-farm wages are higher than farm wages. In the case of Whites and Coloureds the only source of supply is that of the non-farm sector in which case the wage obtained there is the opportunity return. As discussed in section 3.3 Bantu labour can be drawn from the subsistence sector which makes it difficult to assess their opportunity return because this labour can also be employed in the non-farm sector.

The MP of labour could also be high because the remuneration of labour is underestimated by the data used. No allowance was made for the following forms of compensation; free housing, free grazing and crop land set aside for tenants and full-time employees.

The marginal product for land is very low as in the case for the

aggregate production function. From a theoretical point of view this implies that land is abundant and a reduction in farm size accompanied by a more intensive use of the remaining land will increase production. Marginal products of land close to 100 or greater than 100 were found for agro-economic regions A, B and K, which are the irrigation and cropping regions.

The fact that farmers are prepared to pay a higher price for land than its marginal product may be because they are expecting a future increase in the price of land. This is a reasonable expectation as prices of land in South Africa increased from an index of 49 in 1942/43 to an index of 340 in 1964/65 with 1947/48 - 49/50 = 100. This is a weighted price for land in the maize, wheat, cattle and sheep areas in South Africa (32). This however does not explain why MP's of land are zero or even negative in certain areas. Land was measured in terms of value to take quality differences into account. It appears to be quite a reasonable assumption that the productivity of land is reflected in its price. Further, by grouping farms in agro-economic areas it becomes more difficult to say that something was wrong with the method of analysis. If farms are of the same average size in the various regions, then the different land inputs will resemble a point and it will also be impossible to estimate the effect of this variable. In this case measurement errors will become very serious. The average size of farms was however found to vary substantially.

The MP's of livestock for all the regions are very high, indicating that profits can be increased substantially by increasing the stocking rate. The high marginal products of the livestock variable can to a certain extent be expected. This is because the total cost of livestock is small in comparison with factors like land, and besides

this an almost one to one relationship exists between livestock numbers and profits from livestock. The adverse effect of an increase in stocking rate on next year's profits is of course not accounted for here.

The marginal products of machinery were only estimated for the A, B and K regions where they were considerably in excess of 100. For these regions the marginal products of machinery were higher than the marginal products of labour, land, and current expenditure. The marginal products of current expenditure did not deviate very much from 100 for the A and B regions but for the M region this factor had a 28% higher marginal product.

In this study it was shown that income could be increased by increasing the stocking rate. The result warrants closer investigation. Various prominent farm leaders in South Africa have warned against the abuse of veld by overstocking and improper management whereby the vegetation deteriorates both in vigour and in quality, and the soil becomes exposed to wind and water erosion (122, p. 3) (33, p. 9) (62, p. 10) (95, pp. 5, 10). In areas such as the Karoo it appears that nature has put an absolute limit on the stocking rate more than anywhere else. In other areas more scope exists for the integration of the animal factor in the overall farming system. Various farms have been planned by the use of linear programming at the University of Natal by final year and post-graduate students and in the majority of cases income was raised substantially by increasing livestock numbers. It was possible to raise the farm income in the linear programme solution by choosing the optimum combination of forage crops.

It should be possible to raise the stocking rate in some parts of South Africa through an improvement of pasture management. Total income from livestock can be increased by increasing the productivity per unit or by increasing the number of units. It is, for example, uneconomical to raise milk production per dairy cow (gallons) to a maximum if net income can be further increased by increasing the number of cows, resulting in less milk produced per animal unit. This is the case when diminishing returns from feed intake for every cow is assumed. The cost of an additional cow must also be considered here.

The high marginal product for livestock may be attributed to some extent to the aggregation of farming units into magisterial districts (129). Aggregation, however, could not have influenced the marginal product of variables to such an extent. Another reason may be advanced. The quality of the land may be better reflected in the stocking rate than in its own price. If this is true then it explains why the MP of livestock is very high while the MP of land is low. The elasticity of livestock is then overestimated while the elasticity of land is underestimated (48). The quality of the land is a very important factor in the production function. If this variable is highly correlated with the stocking rate then this may cause an overestimation of the livestock variable. In this study the land input was measured by its value. If the number of animal units on a farm is a better indication of the quality of land than the value of the farm, then the land input will be underestimated. It may be expected that this effect is negligible if the animal factor is not important in the farming system. A fair amount of measurement error is present in the land input. The value of the land is a subjective estimate

of the farmer as reported in the agricultural census reports. This may not be at all a true reflection of land quality in various regions. Reading from this it does appear as if the "true" marginal product of land should be higher than the estimation thereof.

Collett (19) could not find any conclusive evidence that total production affected land values in South Africa in a time series analysis. With an elasticity of product demand of less than one, increased production should depress land values. However, doubt exists as to whether the weighted average of domestic and export demand elasticities is less than one, as about 40% of the total agricultural production is exported. On the other hand, if production is in the first irrational zone for other inputs, keeping land constant, then increases of the land input should have a negative effect on production. Strong doubts exist as to whether this is true in the case of a developed society such as the European agricultural sector in South Africa. Thus if production increases are not reflected in higher real values of land, then it does not follow automatically that the land input, as measured by the value of land, must have no influence on production.

CHAPTER 5.

RESOURCE DEMAND FUNCTIONS FOR OPERATING INPUTS
AND LABOUR

In this chapter demand for fertilizer, feed, fuel and lubricants and labour will be estimated by least squares.

5.1. The construction of a resource demand function

The model described in equation 5.1 can be considered as the foundation of empirical resource demand analysis. The demand for a factor is treated as a derived demand, derived from the demand of the product, the production function and the supply conditions of other factors of production (53, p. 184).

$$X_i = f\left(\frac{P_i}{P_Y}, \frac{P_j}{P_Y}, X_k\right) \quad 5.1$$

X_i = consumption of i^{th} factor

P_i = price of i^{th} factor

P_Y = price of product

P_j = prices of variable factors $j = 1 \dots n$

X_k = quantities of fixed factors $k = 1 \dots m$.

While prices of variable factors are included in the demand model, the quantities of fixed factors are considered. In the models reported in this study a budget constraint was also incorporated by the inclusion of an income variable. The same model (5.1) was also fitted for capital (durable) items in Chapter 6. The demand for a durable input was considered as an investment demand and treated separately (65).

Heady and Tweeten (76, p. 48) show how the demand model 5.1 can be used to explain an inelastic commodity supply. For the

inputs that are supplied from the farm sector an increase in product price may cause an imputed increase in factor prices. The stable input price/product price ratio will have the effect that X_1 in model 5.1 may change very little.

The use of price ratios, suggested by static theory, implies a symmetry in response of the input quantity demanded to product and factor prices. Thus if input and output prices increase or decrease by the same proportion, the quantity demanded remains unchanged. The demand function is homogeneous of degree zero. If all prices change by the same proportion then the demand quantity remains unchanged.

Dynamic economic theory questions the validity of price ratios. Farmers make decision of how much to use of an input on the basis of expected rather than actual product prices because of the length of the farm production period. This expected price is according to Tweeten, a subjective estimate on the basis of the permanent and transitory components of current and past prices (132).^{*} Because there is less uncertainty about future input prices than about future output prices it may be reasoned that the permanent component makes a much greater proportion of the input price than of the output price. If farmers make decisions on the basis of the "permanent" component then a given change in input price will have a greater influence on quantity of the input demanded than the same percentage change in product price.

The advantages of price ratios are: (a) reduction of multicollinearity because the original model is collapsed into one with fewer variables (42, pp. 26-30); (b) increased degrees of freedom

* Tweeten most probably took the idea from the permanent income hypothesis of Friedman (41). Friedman used permanent and transitory components of consumption and income, to explain the consumption function.

because of (a), and (c) avoidance of errors from the use of other general price deflators.

Although the use of price ratios is not strictly correct from a logical standpoint, the advantages may justify their use.

The Interstate Managerial Survey indicates, though inconclusively, that farmers respond more readily to input price changes than to output price changes. From a sample of farmers questioned, 51% reported that a change in input price had affected their production and 41% reported that a change in output price had affected their production (8, pp. 458-469). Studies by Heady and Yeh (77, pp. 332-348) and Cromarty (21, pp. 323-331) support the hypothesis of symmetry in response to input and output price changes by farmers.

Because of serious intercorrelations and a limited number of observations, price ratios have been used throughout the demand for input section. Several attempts have, however, been made to estimate product and factor price elasticities separately but in each case the product price variable has turned out to be negative, contrary to expectations in accordance with economic theory.

Single equation regression analyses were used as it was found that farmers were not able to influence the prices of their inputs in any way. The input market, with the exception of labour, in South Africa is of an oligopolistic nature with only a few large suppliers. These firms announce their prices early in the year and rarely vary it in the season. In the short run the price paid by the farmer may thus be considered as predetermined.

Because census data were only available for a limited number of years, dummy variables were used for provincial data to increase the degrees of freedom. These variables increased the problems of

multicollinearity somewhat. The method of including regional data in one model allows the researcher to make comparisons between the regions.

In order to make an allowance for a possible lag in response, the partial adjustment model was used which leads to exactly the same reduced equation as Cagan's adaptive expectations model (18), except that it does not induce additional serial correlation in the disturbances if there were none initially (57, p. 16). Griliches (57, p. 33) showed that if the true equation is not a distributed lag model but instead has serially correlated residuals, then the introduction of a lag variable will usually give significant coefficients and reduce the serial correlation, even though it is not the true equation.

5.2. Demand functions for fertilizer

5.2.1. Introduction

The consumption of plant nutrients in fertilizer in South Africa more than trebled from 1953/54 to 1966/67, and this is a remarkable and by far the greatest resource change in this country during the last decade.

A farmer can buy fertilizer in any amount because it is highly divisible. He can easily adjust purchases as price, weather and other variables change.

According to Fig. 5.1 there appears to be a symmetric response in consumption caused by a decline in the fertilizer to crop price ratio. The important technological changes in the fertilizer industry, according to Griliches (49), were not so much about the discovery of new facts on the use of fertilizer or the spread of knowledge, but in the discovery of new processes of producing fertilizer.

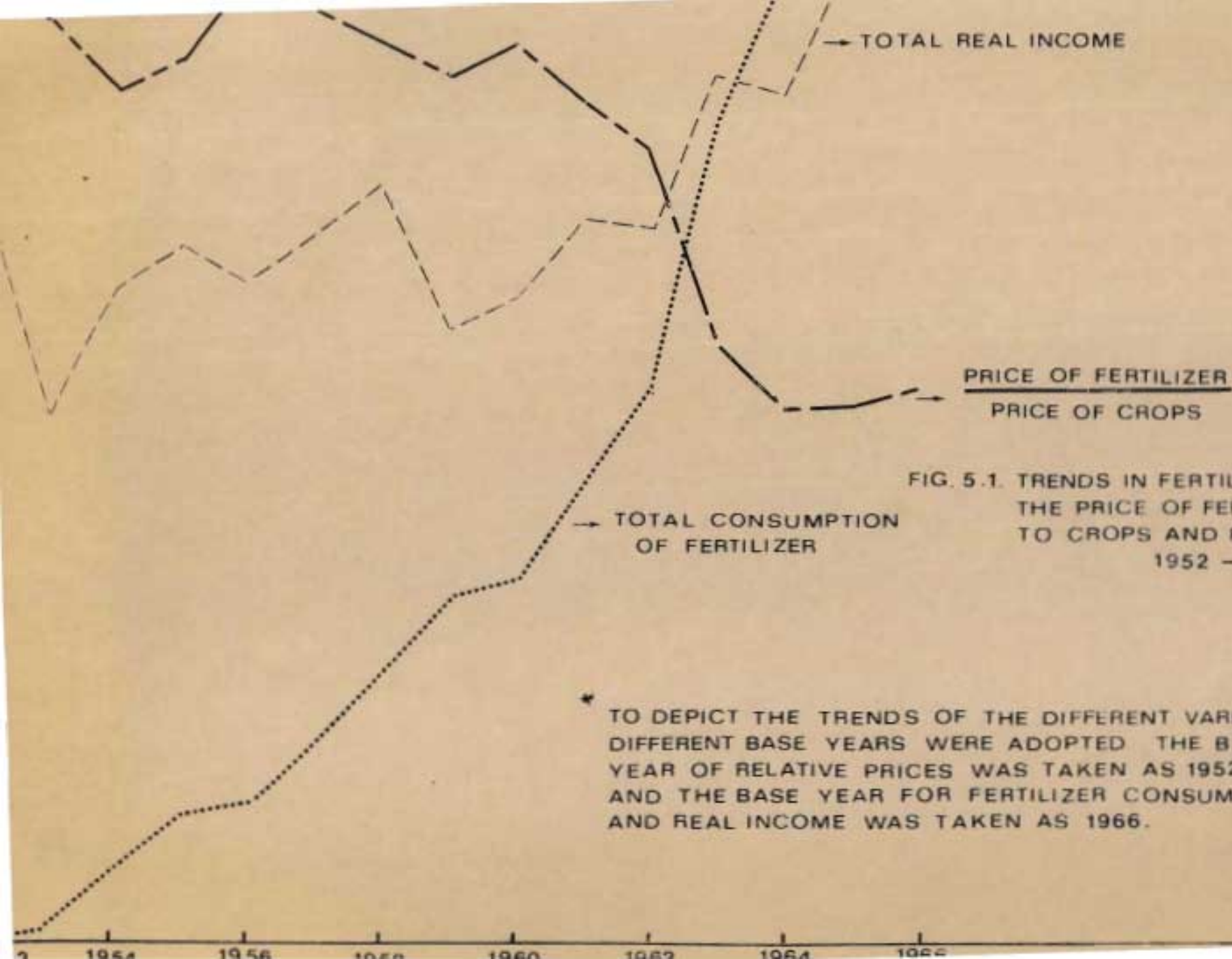


FIG. 5.1. TRENDS IN FERTILIZER CONSUMPTION
THE PRICE OF FERTILIZER RELATIVE
TO CROPS AND REAL FARM INCOME.
1952 - 1966

* TO DEPICT THE TRENDS OF THE DIFFERENT VARIABLES.
DIFFERENT BASE YEARS WERE ADOPTED. THE BASE
YEAR OF RELATIVE PRICES WAS TAKEN AS 1952
AND THE BASE YEAR FOR FERTILIZER CONSUMPTION
AND REAL INCOME WAS TAKEN AS 1966.

Results reported in this chapter for South Africa are similar to that of Griliches. The price of pure plant nutrients for example, decreased by approximately 17% in South Africa during the period 1952-1966.* Crop prices increased during the same period.

From Fig. 5.1 it also appears that income of farmers may also have an effect on purchases.

The first researchers probing into this field of demand for fertilizer thought that farmers spend a constant share of their income on fertilizer** (49). Griliches (49) completely omitted income from his resource demand models because he said there is no theoretical reason for including it as it is not derivable from the traditional theory of the firm. He sees the increase in fertilizer consumption as solely a response to a decrease in the fertilizer/product price ratio. In more recent research (99) (132) both income and relative prices were tested in the same model.

Alternative models were used in this study to test all the variables that may explain fertilizer purchases. Other variables which could not be quantified may also have an effect on fertilizer productivity like irrigation, improved seed varieties and weed control.

No attempt is made in the analysis to determine the decision-

* Indexes of fertilizer prices of the Division of Agricultural Marketing Research show an increase in fertilizer prices for the corresponding period. This is because the indexes of the Division are based on the total volume of fertilizer whereas in this study price of fertilizer is expressed in terms of plant nutrients.

** This concept of interpolating inputs was used by the Division of Agricultural Marketing Research, making the series from a demand analysis point of view useless for certain years.

making process which the individual farmer uses in deciding the quantities of fertilizer desired. The purpose is to explain why fertilizer consumption increased on an aggregate basis and to predict future consumption. The identification of factors influencing the demand for fertilizers is of great use to a developing country. This study should also throw some light on the possible effects of subsidies on fertilizer consumption. Estimates can also be made of the consequences of other types of government intervention in the agricultural industry such as the fixing of the prices of certain products.

5.2.2. Discussion of variables

Time series demand functions were derived for the 15 year period, 1952-1966 and for the 25 year period, 1943-1967.

- F_1 = Consumption of pure plant nutrients (N, P and K) in tons on a calendar year basis.
- F_2 = Weighted consumption of pure plant nutrients in tons on a calendar year basis.
- $P_{Fw}(t)$ = Price of plant nutrients deflated by the wholesale price index for year t . (Calendar year, 1952 = 100).
- $P_{FC}(t)$ = Price of plant nutrients deflated by the price of crops for year t . (Calendar year, 1952 = 100).
- $P_F(t)$ = Price of plant nutrients calculated from weighted consumption data deflated by the wholesale price index for year t . (Calendar year, 1952 = 100).
- $P_{Lw}(t)$ = Price of land deflated by wholesale price index for year t . (Calendar year, 1952 = 100).
- $P_C(t)$ = Price of crops in year t . (1952 = 100).
- $I_w(t)$ = Cash income from farming in thousand rands deflated by

the wholesale price index and lagged six months. (Split year basis, price index 1947/48-49/50 = 100).

$I_I(t)$ = Cash income in rands from farming deflated by prices of farm inputs including labour and lagged six months. The period 1947/48-49/50 was used as a base for input prices.

$C_u(t)$ = Capital assets in million rands on a calendar basis, undeflated.

$C_o(t)$ = Capital assets in million rands at constant prices on a calendar year basis. (1947/48-49/50 = 100).

The variables can be further explained as follows:

Nutrient consumption (F)

The dependent variable is the simple sum of tons of pure N, P and K assuming that farmers attach the same importance to the different components. In an attempt to improve the model, the purchases of individual plant nutrients were also weighted by their respective price coefficients. The assumption is made that farmers are only interested in the weight of plant nutrients applied and not in the total weight of the fertilizers. For the period under study the usage of plant nutrients increased at a higher rate than that of total consumption because fertilizer concentrations increased per unit of weight of fertilizer.

Real or relative price of fertilizer (P_F)

Price indexes of fertilizer were computed by dividing the expenditure on fertilizer by the consumption of nutrients. In determining the cost of fertilizer to the farmer, the subsidy on fertilizer was also considered. The fertilizer price is thus calculated

as:
$$\text{Price} = \frac{\text{Total expenditure on fertilizer minus subsidy}}{\text{consumption of plant nutrients}}$$

This price index was deflated by the crop or wholesale price index of the same year. Farmers know the prevailing fertilizer prices, but can only guess at crop prices for the rest of the year. This indicates that farmers buy fertilizers on the basis of current fertilizer prices but past crop prices. However, because the greater part of fertilizer is sold during the latter part of the year in South Africa the price of fertilizer was deflated by crop prices of the same year. Because of price stabilizing measures under the Marketing Act prices of summer and winter cereals do not vary much from year to year.

Cash income of farmers (I)

This includes cash income and home consumption of farm products minus wages, salaries, interest and rent. Fertilizer companies in South Africa are aware of the fact that more fertilizer is sold when a good crop is expected or harvested.

The expected sign of this coefficient is positive because a priori reasoning indicates that an increased demand for fertilizers is associated with a higher level of income and because higher incomes improve the liquidity position of farmers. When capital is limited, farmers will be unable to fertilize at optimum rates. Under these conditions the marginal cost of resources will be equated with, but it will be less than, the corresponding marginal revenue. An increase in income will thus encourage farmers to move towards the optimum level of fertilization. Fertilizer studies conducted in South Africa also indicate that this factor is applied at lower than optimum levels.

Capital assets (fixed)

In addition to income this variable is a measure of purchasing power. Capital assets are an indication of the borrowing capacity of

the farmer. The level of capital assets may also influence the productivity of fertilizer. Capital assets include machinery, implements and vehicles, livestock, fixed improvements and land. A weighted price index for capital assets was derived, based on 1947/48-49/50 weights. This variable was used to deflate the value of capital assets.

Prices of related inputs

The relationship between the consumption of fertilizer and the price of land can be expected to be positive as this is an indication of a substitution of fertilizer for land.

5.2.3. The results

Models reported are based on national and provincial data.

5.2.3.1. Aggregate demand functions with plant nutrients unweighted based on the 1952 - 1966 period.

If fertilizer prices are determined independently of off-farm purchases, the demand for fertilizer can be estimated with a single equation. The t values are given in parentheses, below the regression coefficients.

$$F_1 = -13.4051 - .9332 P_{Fw}(t-1) + .8222 I_v(t) + 1.140 P_{Lw}(t-1) + 1.708 C$$

(t=1.75)
(t=1.45)
(t=4.31)
(t=2.60)

5.2.

$$R^2 = .958$$

$$d^* = 2.19$$

$$df = 9$$

- * The statistic "d" is a Durbin-Watson serial correlation test. Value near 2.0 indicate a random distribution of errors, values less than 2.0 and approaching 0 indicate increasing positive autocorrelation, and values more than 2.0 and approaching 4.0 indicate increasing negative autocorrelation. Here d is greater than the value of the upper d for 14 observations, 5 exogenous variables and a 5% significance level. So the data are not sufficient for rejection of the hypothesis of independence.

Equation 5.2 is estimated under logarithmic transformation of variables.

All the coefficients of equation 5.2 have the correct signs according to economic theory. The elasticities may be considered as of a long run nature. Multicollinearity became a serious problem when the lag consumption of fertilizer was introduced as an additional variable. It was consequently impossible to make reliable estimates of short run and long run elasticities. The lag price of land variable is significant at the .99 probability level and the capital assets variable at the .95 level.

Malinvaud (96, pp. 22-23) shows that the coefficient of an independent variable in a model changes very little when another variable is introduced which is not correlated with it. In the present study independent variables were correlated to a degree and variables in some models were found to be very sensitive to new variables introduced.

A 1 percent decrease in fertilizer price in the current year, other things remaining equal, is predicted to increase fertilizer purchases by .9 percent in the next year. Similarly, a 1 percent increase in real income is predicted to increase fertilizer purchases by .8 percent in the present year. A lag income variable was not significant when tested simultaneously with an income variable. At present fertilizer companies recognise the effect of good and bad years on the purchases of fertilizers but they have not been able to measure it.

The cross price elasticity of fertilizer purchases with respect to the lag price of land is positive and unitary indicating that fertilizers are good substitutes for land. A 1 percent increase in the lagged price of land is predicted to lead to a 1 percent increase in fertilizer consumption. However, a farmer purchases fertilizer

to use on his given acreage, and not directly to substitute for land by reducing acreage (76, pp. 106, 110, 165). Because the marginal products of fertilizer decline as more is applied on a given area, the inference can be made that land and fertilizer substitute at a diminishing rate.

The land price variable was more significant than any of the other variables. This may be attributed to high correlations between land price and time, and land price and general technological progress. It is highly probable that there exists a strong correlation between the land price and the awareness amongst farmers of the beneficial effect of fertilizers. The effect may also be in the opposite direction: the price of land may be a function of fertilizer inputs. Land productivity increased as a result of factors like better varieties, and the greater use of fertilizer. Because of the increased yields per unit farmers are prepared to pay higher prices for land.

Equation 5.2 also shows that a 1 percent increase in capital assets on farms will lead to a 1.8 percent increase in fertilizer expenditure. The coefficient of capital assets is significant and positive, and indicates the complementarity between fertilizer and durables.

Model 5.2 was also run in original values (Equation 5.3), that is, without transforming it to logarithms.

$$\begin{aligned}
 P_1 = & - 89,494 - 2,756.33 P_{FW}(t-1) + .474299 I_w(t) \\
 & \quad (t=2.40) \quad (t=2.05) \\
 & + 854.307 P_{LW}(t-1) + 78.432 C_o(t) \\
 & \quad (t=2.63) \quad (t=1.74)
 \end{aligned}
 \tag{5.3}$$

$$\begin{aligned}
 R^2 &= .964 \\
 d &= 2.57 \\
 df &= 9
 \end{aligned}$$

Model 5.3 has a better fit than that of 5.2 indicating linear relationships between the exogenous and endogenous variables.

The elasticity of price at the mean level is -1.36 which is higher than that of equation 5.2. The elasticity of income at the mean level is $+1.08$. According to equation 5.3 the income elasticity of demand at the 1966 level is approximately $+ .76$ and at the 1953 level approximately $+ 2.10$. From this it appears that the income elasticity is falling over time. It must be borne in mind that estimates at the beginning or end of the period are more unreliable than estimates at the mean because of the particular shape of the confidence limits.

More models are reported in Table 5.1.

In Table 5.1 both present and past prices of fertilizer are used as exogenous variables. The fertilizer price variable was so highly correlated with other variables in equation 5.4 that it turned out insignificant.

From Table 5.1 and earlier results it appears as if the capital assets variable is stable and is not affected to a great extent by the way in which it is measured. Capital assets variables in a deflated, undeflated, lagged and current form all have approximately the same magnitudes.

A crop price variable was tested in several models but it turned out insignificant with a negative sign. According to economic theory this sign should be positive. In subsequent models the factor to product price ratio was however found to be significant. Hedy and Tweeten (76, p. 173) were also unsuccessful in the estimation of a crop price variable. This is seen as a time series problem with no economic significance.

Based on equation 5.2 demand curves for fertilizer were derived

TABLE 5.1. STATISTICS OF ESTIMATES OF DEMAND FUNCTIONS FOR FERTILIZER, INCLUDING REGRESSION COEFFICIENTS, t VALUES (IN PARENTHESES) AND R^2 . SOUTH AFRICA, 1953 - 1966.

Equation	d	R^2	Log of Constant	$P_{Lw}(t-1)$	$C_u(t)$	$P_{Fc}(t-1)$	$I_w(t)$	$C_c(t-1)$	$P_{Fw}(t)$
5.4	2.52 Hypothesis of indep. not rejected	.949	-24.8291	1.335 ($t = 5.16$)		-.3742 ($t = .77$)	1.278 ($t = 2.21$)	1.982 ($t = 2.79$)	
5.5	1.23 Hypothesis of indep. not rejected	.980	3.2191		1.652 ($t = 6.67$)				-1.181 ($t = 4.26$)

The elasticities of Table 5.1 are in agreement
with earlier results.

and presented in Fig. 5.2. Real income is kept constant on each demand curve. The demand curve indicated by "B" is drawn at the geometric mean income level of the period under study (1953-66). The demand curve "A" is drawn for the income level of 1953 and the demand curve "C" for the income level of 1966. A higher level of income improves the liquidity position of farms and farmers are encouraged to move towards the optimum level of fertilization.

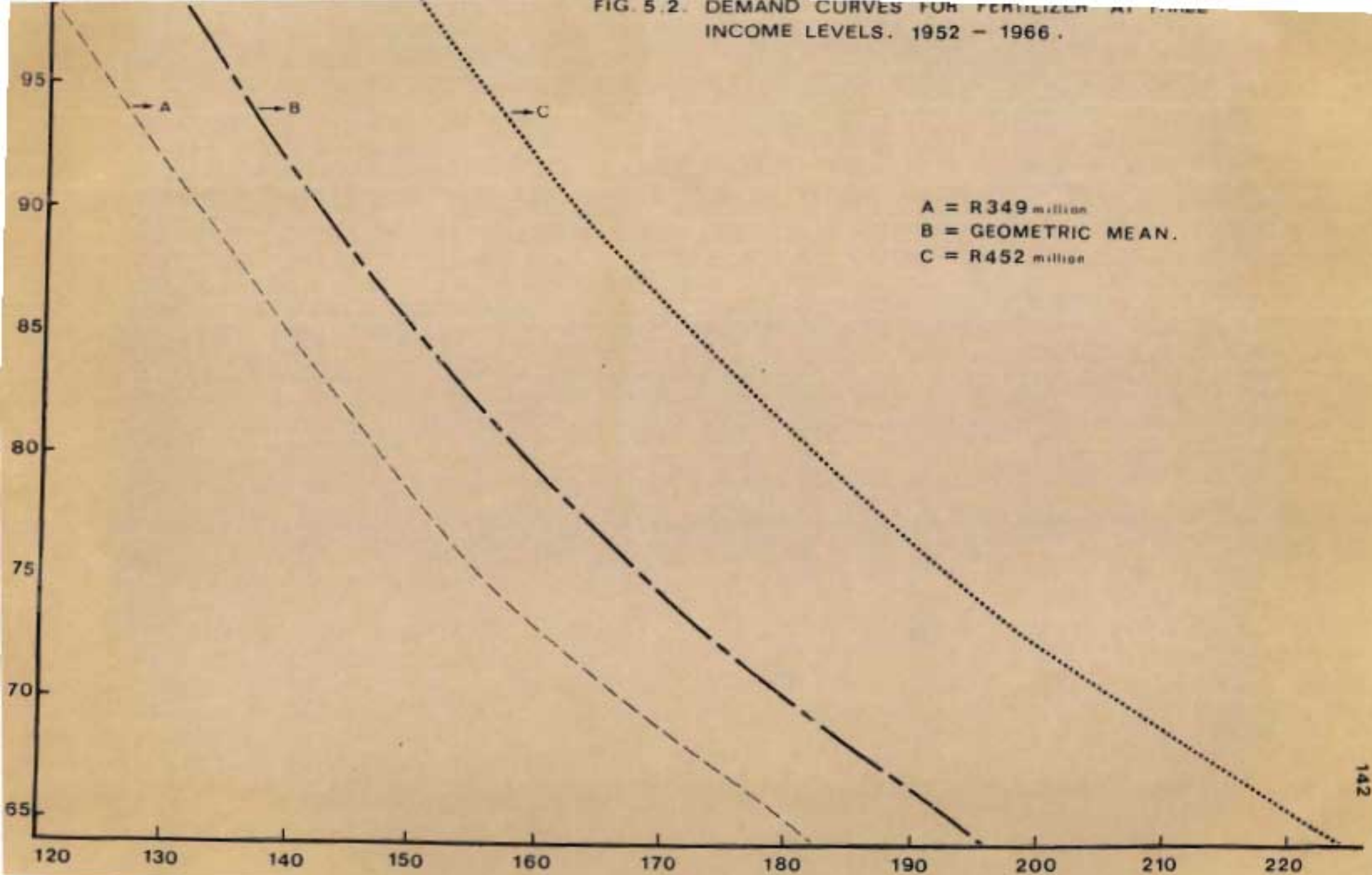
The price elasticity of fertilizer is equal to $-.9$ at any point on the three demand curves. Each demand curve is drawn ceteris paribus; capital assets and land prices are kept at geometric mean levels.

Fig. 5.2 shows very clearly how the demand schedule shifts to the right with increased income. This has the effect that more fertilizer is purchased at the same price level. It also shows how more fertilizer is purchased with a decrease in the price, other things being the same. It is interesting to look again at Fig. 5.1 after having studied Fig. 5.2. In contrast with Fig. 5.1 the "other factors" are kept constant in Fig. 5.2.

5.2.3.2. Aggregate demand functions for fertilizer with weighted plant nutrients for the 1952 - 1966 period.

While in the earlier models the nitrogen, phosphate and potash contents of all fertilizers were simply added together to arrive at the total plant nutrient tonnage, the individual nutrients are here weighted by their relative prices before being aggregated. The weights used were derived from a multiple regression of fertilizer prices for different mixes of fertilizer for South Africa (1967) on the respective percentage content of the three nutrients.

FIG. 5.2. DEMAND CURVES FOR FERTILIZER AT FIVE
INCOME LEVELS. 1952 - 1966.



A random sample of 19 fertilizer mixes from different companies* was used for this purpose.

The following equation was consequently fitted on original data:

$$Y = 6.54 + 1.196 N + 2.612 P + .828 K$$

(t=9.34) (t=6.10) (t=5.83) 5.6

$$R^2 = .876$$

$$d = 2.52$$

$$df = 15$$

Y = Total cost (value) of fertilizer mixture.

N = Percentage nitrogen content of the mixture.

P = Percentage phosphate content of the mixture.

K = Percentage potash content of the mixture.

The partial regression coefficients of N, P and K were significant at the .001 level of probability.

Using the partial regression coefficients of equation 5.6 as weights, weighted aggregate demand equation 5.7 was estimated.

$$F_2 = - 4.3422 - 1.207 P_{FW}(t-1) + 1.3884 P_{LW}(t-1) + 1.9275 C_o(t)$$

(t=2.73) (t=6.03) (t=2.58) 5.7

Loge used

$$R^2 = .9072$$

$$df = 10$$

$$d = 1.87$$

All the variables in model 5.7 have signs expected on the basis of economic theory. The land price variable is significant at the .001 level of probability and the price of fertilizer and

* Prices of fertilizer mixes were obtained from Mr. H.S. Hattingh, of the Division of Agricultural Production Economics, Pretoria.

capital assets variables are significant at the .05 levels.

The partial regression coefficients are equal to the elasticities of the variables because the equation is in terms of logarithms.

The elasticities of equation 5.7 are within the ranges of the earlier results based on unweighted nutrients. Griliches (49, p. 91) and Metcalf and Cowling (99, pp. 375-386) used a similar weighting procedure but, as in this study, they could not detect a significant difference between the weighted and unweighted regressions.

A general impression is that the weighting procedure as applied in model 5.7 was very successful in the sense that the Durbin-Watson statistic is close to two, the coefficients more than twice the standard errors and the R^2 high.

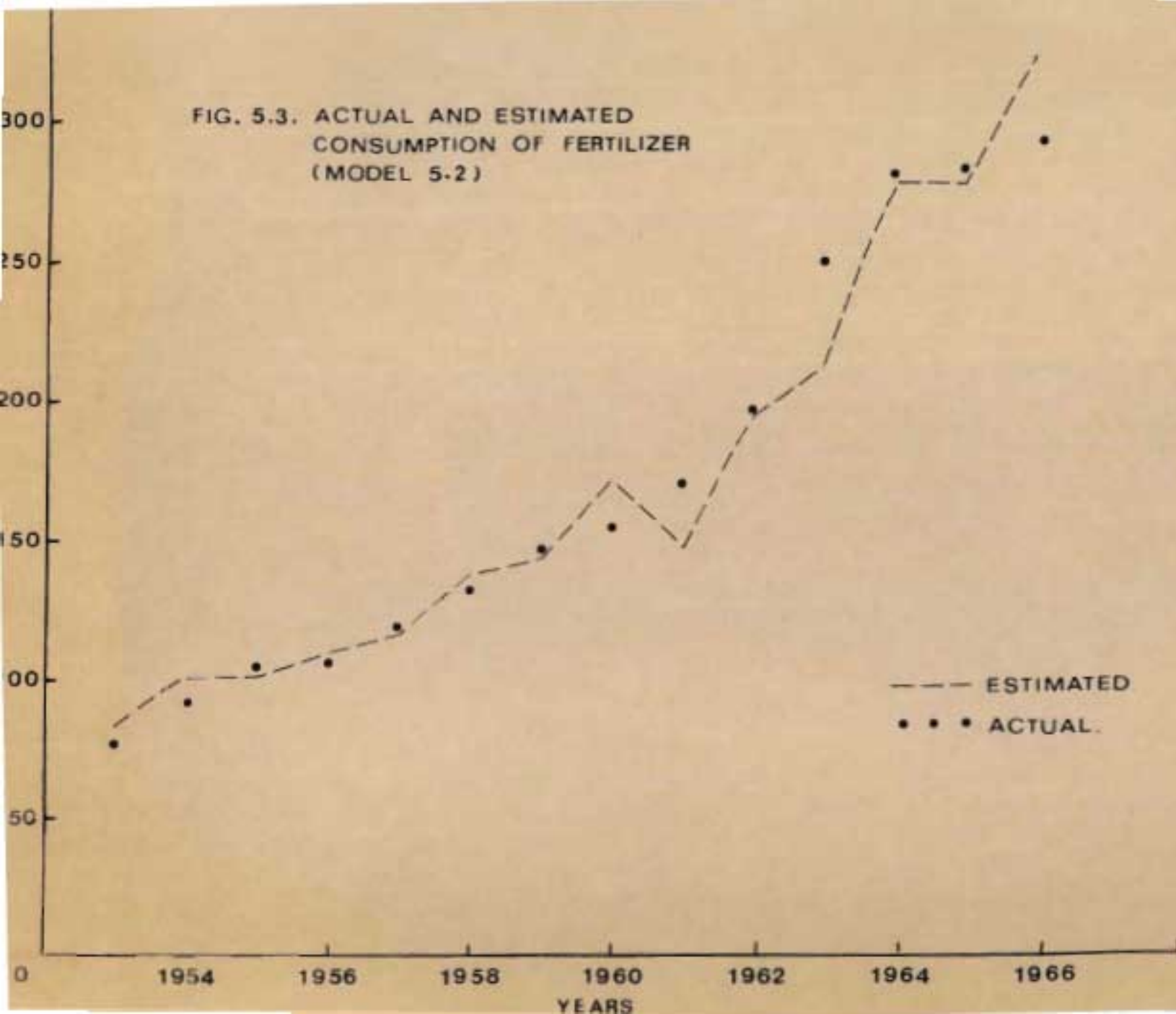
Fig. 5.3 shows the actual and estimated consumption of fertilizer in thousand tons. Fertilizer consumption was estimated from equation 5.2. The graph gives the impression that the model could not explain fertilizer consumption after 1959 as accurately as before 1959.

5.2.3.3. Aggregate demand function with plant nutrients unweighted for the period 1943 - 1967.

As mentioned before, some of the models presented may be criticized on the grounds of low degrees of freedom. Because of the uncontrolled "experiments" in the economic world and the correlation between independent variables, more degrees of freedom should be required to obtain meaningful answers than in the controlled biological sciences.

The aggregate demand models presented so far are based on fertilizer consumption figures calculated by the Division of

FIG. 5.3. ACTUAL AND ESTIMATED
CONSUMPTION OF FERTILIZER
(MODEL 5.2)



Agricultural Marketing Research for the period 1952-1966. Professor E.R. Orchard, Head of the Soil Science Department at the University of Natal, independently of the Division, derived fertilizer consumption figures in pure nutrient form for the period 1943-1967. This thesis had already reached a draft form when the writer learned of these figures and, because of the longer period covered, it is now incorporated into the analysis.

Since the adjustment to changes in independent variables takes time, the distributed lag model was estimated for fertilizer demand. This model can be explained as follows where Y_t^H is the desired level of use, p stands for a vector of all relevant prices and the coefficients of $f(P_t)$ are interpreted as long run coefficients (50, p.310)

$$Y_t^H = f(P_t) \quad 5.8$$

Equation 5.9 is an adjustment model which implies that the actual change in Y is proportional to the difference between the present "desired" level and the past achieved level. The adjustment coefficient is b . When b is equal to one, instantaneous adjustment is implied and when b is close to zero, the adjustment to changes in independent variables is very slow.

$$Y_t - Y_{t-1} = b (Y_t^H - Y_{t-1}) \quad 5.9$$

Substituting 5.8 into 5.9 yields 5.10 which was estimated by ordinary least squares.

$$Y_t = bf(P_t) + (1 - b) Y_{t-1} \quad 5.10$$

The coefficients of $bf(P_t)$ are of "short-run" nature and the adjustment coefficient can be derived from the estimate of $(1 - b)$.

In Table 5.2 fertilizer demand models are presented for the period 1943-67. These equations show a vast improvement in fit on

TABLE 5.2. STATISTICS OF ESTIMATES OF DEMAND FUNCTIONS FOR FERTILIZER, INCLUDING REGRESSION COEFFICIENTS, t VALUES (IN PARENTHESES) AND R^2 . SOUTH AFRICA, 1943 - 1967.

Equation	df	d	R^2	Constant	$P_{Fc}(t)$	$C_u(t)$	$I_I(t)$	$F_1(t-1)$
5.11 (0)	21	1.50	.980	153,363	-1,482.56 ($t = 3.70$)			0.7915 ($t = 9.00$)
5.12 (L)	20	1.38	.991	3.8450	-0.8110 ($t = 5.54$)		.2973 ($t = 1.84$)	.6479 ($t = 9.38$)
5.13 (L)	21	.77*	.986	2.6603	-1.1925 ($t = 5.84$)	1.0101 ($t = 5.04$)	.4485 ($t = 1.42$)	
5.14 (L)	21	1.63	.989	6.0749	-.7078 ($t = 4.96$)			.7458 ($t = 16.05$)

0 = original. L = logarithm.

* Hypothesis of independence rejected.

those models based on the shorter period.

Making an allowance for a lag in adjustment, 99% of fertilizer purchases is explained by the price of fertilizer relative to crops, in model 5.14. The variables fitted in this model are highly significant. This result supports Griliches' contention that fertilizer purchases can be explained solely by the fertilizer/product price ratio (4) (50) (51).

In equation 5.14 the adjustment coefficient is estimated as $b = .25$. In the same model the short run price elasticity is estimated as -0.71 and the long run price elasticity as -2.79 . In Griliches' model (49, p. 602) the adjustment coefficient was estimated at $.25$ which is the same as the result obtained above. He also estimated the elasticity of demand with respect to the price of crops to be $-.5$ in the short run and -2.0 in the long run. From this and other models reported it does appear as if the price elasticity of fertilizer is higher in South Africa than in the U.S.A. Griliches believes that his estimate of the long run elasticity is somewhat too high and his estimate of the adjustment coefficient is somewhat too low due to omission of other relevant variables. He also stresses that he has not been able to improve on these results by including other reasonable variables like the price of land and the prices paid for other inputs.

The introduction of an income variable as in model 5.12 contributed little to the portion explained. The adjustment coefficient increased to $b = .35$ and the short and long run elasticities are estimated respectively at $-.61$ and -2.30 for prices and $+.30$ and $+.84$ for income.

With an adjustment coefficient of .25 almost 80% of the indicated adjustment is completed within 5 years (49, p. 602) and with an adjustment coefficient of .34 approximately 90% is completed. The long run does appear to be "far away".

In equation 5.13 about 99% of the variation in purchases was explained by the "real" price of fertilizer, income of farmers and the stock of assets. Assuming an instantaneous adjustment process, the price elasticity increased to -1.2 in this model. The Durbin-Watson statistic is however smaller than the lower bound and the hypothesis of independence is consequently rejected.

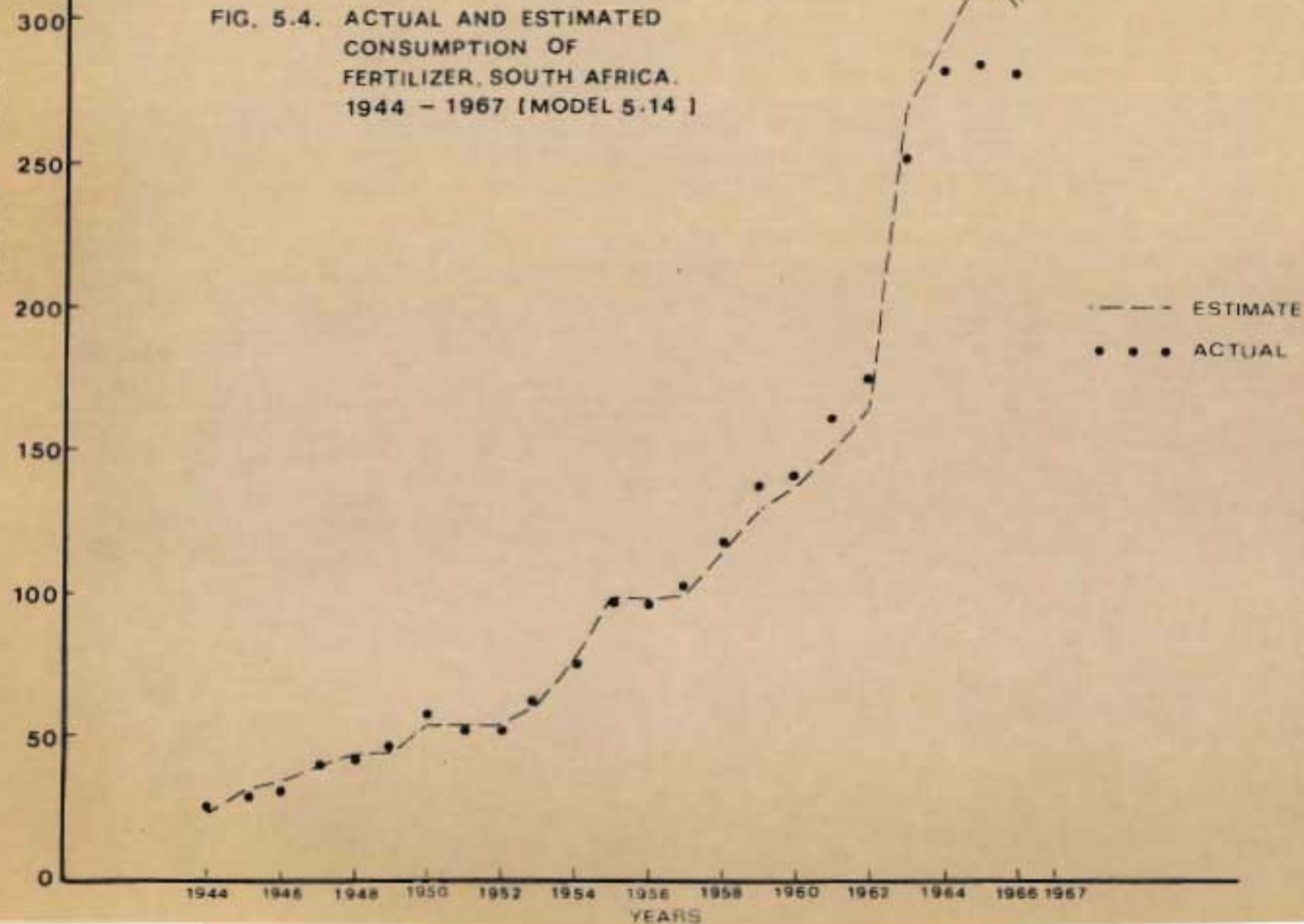
The actual amounts of fertilizer purchased and the estimated quantities based on equation 5.14 are portrayed in Fig. 5.4 for the period 1944-1967. The model predicts consumption well except that it overestimates during the years 1964-1966. This may partly be attributed to drought conditions that prevailed. For example gross value of maize production declined from an average of R188 m for the period 1961-1963 to R148 m for the period 1963-1965 (31). In model 5.14 only the price effect was considered and the reduction in spending power was neglected. This conclusion is supported by estimations from equation 5.12 which overestimate consumption only slightly during the period 1964-1966. In this equation the income variable was included.

5.2.3.4. Provincial model

The provincial model covers the period 1937 - 1963 excluding 1938 - 1945, 1948 - 1949, 1951 and 1955 because of the lack of census data. Equation 5.15 is estimated in the original form.

FERTILIZER CONSUMPTION IN THOUSAND TONS

FIG. 5.4. ACTUAL AND ESTIMATED
CONSUMPTION OF
FERTILIZER, SOUTH AFRICA.
1944 - 1967 [MODEL 5.14]



$$\begin{aligned}
 Y_t = & -681 + 4,964 X_1 + 1,413 X_2 + 17,571 X_3 + 85.11 I \\
 & (t=.82) \quad (t=.27) \quad (t=5.95) \quad (t=4.99) \quad 5.15 \\
 & + 664.3 P_L - 237.8 P_F \\
 & (t=1.94) \quad (t=1.49) \quad R^2 = .802 \\
 & df = 53
 \end{aligned}$$

Y_t = Tons of plant nutrients.

I = Provincial gross income in million rands deflated by the consumer price index. Price index 1947/48 - 1949/50 = 100.

Incomes from the following field and horticultural products were considered: maize, wheat, sugar cane, deciduous fruit and viticultural products. These products contribute about two-thirds of the income from field and horticultural products.

P_L = Price of land in rand per morgen on a provincial basis deflated by the consumer price index. Price index 1947/48 - 1949/50 = 100.

P_F = Price of fertilizer deflated by the crop price index 1947/48 - 1949/50 = 100.

Tr = Tractors on farms.

X_1 = 1 if Cape, 0 otherwise;

X_2 = 1 if Natal, 0 otherwise;

X_3 = 1 if Transvaal, 0 otherwise; if $X_1 = X_2 = X_3 = 0$, then Free State.

The income elasticity of 1.19, as derived from the coefficient in equation 5.15, is significant at the .001 level. This elasticity was more significant and absolutely greater than the elasticities of land and fertilizer price. If earlier results are also considered then it appears that the income elasticity is marginally greater than unity.

The fertilizer price elasticity is -.88 and cross price

elasticity of land is +.48. The provincial price elasticity for fertilizer is close to the elasticities based on national data. The positive cross price elasticity supports earlier findings that land and fertilizer substitute for one another, but the elasticity is considerably smaller.

The introduction of dummy variables pushed up the degrees of freedom to 53 which is a substantial improvement on earlier models.

The zero-one variables for the Cape and Natal were not dropped because of the problem of regrouping the data. To test the hypothesis of no regional differences, the joint hypothesis $H_0: X_1 = X_2 = X_3 = 0$ must be tested.

It also seems reasonable that the introduction of the tractor into the farming enterprise could have had a stimulating effect on fertilizer consumption. A demand model (in the original form) with tractor numbers and price of fertilizer relative to crops was found to explain purchases of fertilizer even better than the previous equation. Both variables are significant at the .001

$$Y_t = 36,542 + 182 X_1 + 6,814 X_2 + 9,941 X_3 - 361.0 P_F + 1.037 Tr$$

$$(t=.08) \quad (t=2.40) \quad (t=4.50) \quad (t=3.32) \quad (t=8.49)$$

$$5.16$$

$$R^2 = .910$$

$$df = 54$$

probability level. The price elasticity of fertilizer with respect to crops is -1.33 which is higher than the previous model. A complementary relationship appears to exist between fertilizer and tractors according to the model. A 1% increase in tractor numbers was associated with a .80% increase in fertilizer consumption. The

tractor, as probably the most important single factor in the mechanisation process, must have opened the horizons and scope of applying fertilizers to land previously not cultivated.

5.3. Demand functions for feed

5.3.1. Aggregate demand function

In the following table the elasticities of the demand for feed are shown for the period 1950-1966 excluding 1951 for which no data were available. All the variables were transformed to logarithms.

Equation 5.17 indicates that approximately 84% of the variations in feed consumption can be explained by only two factors, the lag prices of feed and the trend. The price-elasticity of feed also appears to be less than one. According to the less successful equation 5.19, income and capital assets of farms also have an influence on the purchases of feed.

Because the demand for the feed input can be considered as a derived demand from the livestock product, feed prices were deflated by the price of livestock in equation 5.19.

Heady and Tweeten (76, p. 389) found price elasticities of feed with respect to current and past year feed prices of $-.8$ and -1.3 respectively. Equation 5.17 indicates a price elasticity of $-.9$.

5.3.2. Provincial model

The provincial demand model was fitted in original form for the period 1950 - 1963 excluding 1951 and 1955 for which years census data on feed were not available.

TABLE 5.3. MODELS OF THE DEMAND FOR FARM FEEDS PURCHASED IN SOUTH AFRICA FROM 1950 - 1966, OMITTING 1951.

Equation	R ²	Contant	P _A (t)	P _B (t-1)	I(t-1)	C(t)	T	df
5.17 (L)	.839	4.3193		-.884 (t = 1.22)			2.213 (t = 4.36)	13
5.18 (O)	.868	-255.5		143.21 (t = 1.61)			422.71 (t = 4.41)	13
5.19 (O)	.495	-27,933	54.038 (t = .33)		+0.03048 (t = 1.71)	13.659 (t = 1.86)		12

O = Original.

L = Logarithm.

Y = Value of farm feed purchased (in thousand rands) at 1947/48 - 1949/50 prices. Farm feed includes maize, oats, lucerne, teff, dairy meal, laying meal, laying mash, pig meal, bone meal and salt.

P_A(t) = Price of feed deflated by the price of livestock products for the current year, (1947/48 - 1949/50 = 100).

P_B(t-1) = Price of feed deflated by the price index of farm inputs including labour, lagged one year. (1947/48 - 1949/50 = 100).

I(t-1) = Farm income in thousand rands deflated by prices of farm inputs including labour and lagged one year. (Price index of inputs 1947/48 - 1949/50 = 100).

C(t) = Capital assets in million rands at constant 1947/48 - 1949/50 prices.

T = Time measured as the last two digits of the current year.

$$Y = 4,030 + 7,534 X_1 + 1,823 X_2 + 5,355 X_3 + 7.070 I - 51.56 P$$

$(t=16.05) \quad (t=3.40) \quad (t=12.71) \quad (t=3.32) \quad 5.20$

$(t=1.25) \quad R^2 = .928 \quad df = 42$

Y = Provincial expenditure on stock and poultry feed in thousand rands deflated by its price index. Price index 1947/48 - 1949/50 = 100.

I = Gross income in million rands on a provincial basis deflated by the consumer price index. Price index 1947/48 - 1949/50 = 100.

P = Price of feed deflated by the price of dairy products and slaughter stock 1947/48 - 1949/50 = 100.

X_1 = 1 if Cape, 0 otherwise;

X_2 = 1 if Natal, 0 otherwise;

X_3 = 1 if Transvaal, 0 otherwise; if $X_1 = X_2 = X_3 = 0$, then Free State.

A decrease of 1% in the price of feed or an increase of 1% in the price of dairy products and slaughter stock is estimated to stimulate feed purchases by .74%. This is near to the national elasticity of -.89 previously derived.

There appears to be a downward trend in the feed to product price which, if continued, will stimulate the utilisation of purchased feed.

The income elasticity of +.47 is significant at the 1% level. The income elasticity is relatively low. Little reason exists for including income as a scale variable. Farmers may, with more money at their disposal, afford to buy more feed.

The increase in the consumption of poultry feed over the last few years in South Africa cannot be analysed within this framework as it represents a shift of the demand for feed to the right by what

conveniently may be called "technological" forces. Broiler production has been increasing at an unprecedented rate.

Other factors not measured may also have an effect on the demand. Improvement in the nutritive content of feed will have the effect of lowering the per unit cost as in the case of fertilizer. Production is also getting more specialised and certain regions may find it to their relative advantage to produce feed, for example, Calvinia where lucerne may be profitably produced under irrigation. Other regions purchase feed for the same reason. The Karoo farmers buy feed to help their sheep through difficult times.

5.3.3. Aggregate demand for maize used as feed

Maize feed increased from 1.39 m bags in 1936/37 to 8.90 m in 1949/50 and to 19.54 m bags in 1968/69. The animal consumption of maize increased by a greater percentage than the human consumption of maize. From 1949/50 to 1968/69 the animal consumption of maize increased by 119% while the human consumption increased by 68%. During the same period the human consumption however showed a greater absolute increase from 18 m to 30 m bags.

As about 87% of feed purchased is maize, it is desirable to estimate the demand for this item separately. Maize can be measured in bags purchased, which is a homogeneous unit and subjected to less measurement error than an aggregate input such as all feed. Data on consumption of maize are available from 1936/37 to 1968/69 which is a more suitable basis for predictive purposes than the 1950-1966 period for which data are available for all feed.

In Table 5.4 the estimates of maize feed demand models are presented for the two periods, 1944/45 to 1968/69 and 1936/37 to 1968/69. Some models are presented for the post-war period in order

TABLE 5.4. DEMAND FOR MAIZE PURCHASED FOR FEED. SOUTH AFRICA, 1936/37 TO 1968/69 and 1944/45 TO 1968/69.

Equation	Period	R^2	df	d	Constant	P_{MR}	P_{MP}	L_u	L_o	Y_{t-1}
5.21 (O)	1944/45 1968/69	.915	22	1.46	20.97	-.187 (t = 5.47)		.01202 (t = 11.40)		
5.22 (L)	1944/45 1968/69	.910	22	1.05	4.33	-1.574 (t = 5.09)		.8031 (t = 11.89)		
5.23 (O)	1944/45 1968/69	.936	22	2.42	9.71	-.083 (t = 2.52)				.9487 (t = 13.41)
5.24 (L)	1944/45 1968/69	.922	22	2.24	3.62	-.727 (t = 2.32)				.9108 (t = 12.89)
5.25 (O)	1936/37 1968/69	.951	28	2.26	3.58		-.0303 (t = 1.25)			.9997 (t = 22.88)
5.26 (O)	1936/37 1968/69	.797	29	.69	-11.34		-.0379 (t = 1.02)		.0462 (t = 9.92)	

(O) = original

(L) = logarithm

Y_t = Animal consumption of maize in million bags (200 lbs each) for period t.

P_{MR} = Retail price of maize deflated by the producer's price of dairy products. 1947/48 - 1949/50 = 100.

P_{MP} = Producer's price of maize deflated by the producer's price of dairy products. 1947/48 - 1949/50 = 100.

L_u = Livestock inventory in million rands undeflated.

L_o = Livestock inventory in million rands deflated by the consumer's price index with base year 1947/48 - 1949/50.

to eliminate the war years.

The price of maize deflated by the price of dairy products fluctuated little during the period considered, without any definite trend. This may be attributed to the production of maize by the agricultural sector in contrast to other inputs which are produced by the industrial sector.

In models 5.21 and 5.22 the factor product price elasticities, i.e. retail price of maize deflated by producer's price of dairy products, are estimated at -1.76 and -1.57. The elasticities of livestock inventory undeflated, were respectively estimated for the two models as .85 and .80.

The short run price elasticity of maize was estimated at -.79 and -.73 in equations 5.23 and 5.24 respectively. The long run elasticity was estimated in equation 5.24 as -8.15.

In model 5.22 the Durbin-Watson statistic is just greater than the lower bound of this test at the 5% level. Equation 5.26 should be rejected because of the presence of serial correlation. The serial correlation may be due to the omission of relevant variables because of the low R^2 for this model ($R^2 = .797$). It does appear as if the introduction of the lagged dependent variable reduced the serial correlation in model 5.25.

The general impression is that the factor product price ratio and the assets of all livestock estimate the animal consumption of maize fairly well. Allowing for a lag in response, more than 90% of the variation in purchases could be explained by the price of maize relative to the price of dairy products. Probably the most puzzling result is the relatively low short run price elasticity and the relatively high long run elasticity. A small percentage of the

indicated adjustment consequently takes place in the first year. It seems reasonable that relevant variables are omitted from the models estimated. Other feeds like veld grazing may also substitute for maize. If this is the case then the long run elasticity is too high. It may be concluded that the long run demand is elastic but not quite as elastic as estimated.

It does not appear logical that the elasticity of demand for maize is high, while the price elasticity for all feed is less than one. This may be attributed partly to the fact that all feed was measured in values but maize in physical units (bags). The demand elasticities for all feed are approximately of the same magnitude as the short run elasticities estimated for maize.

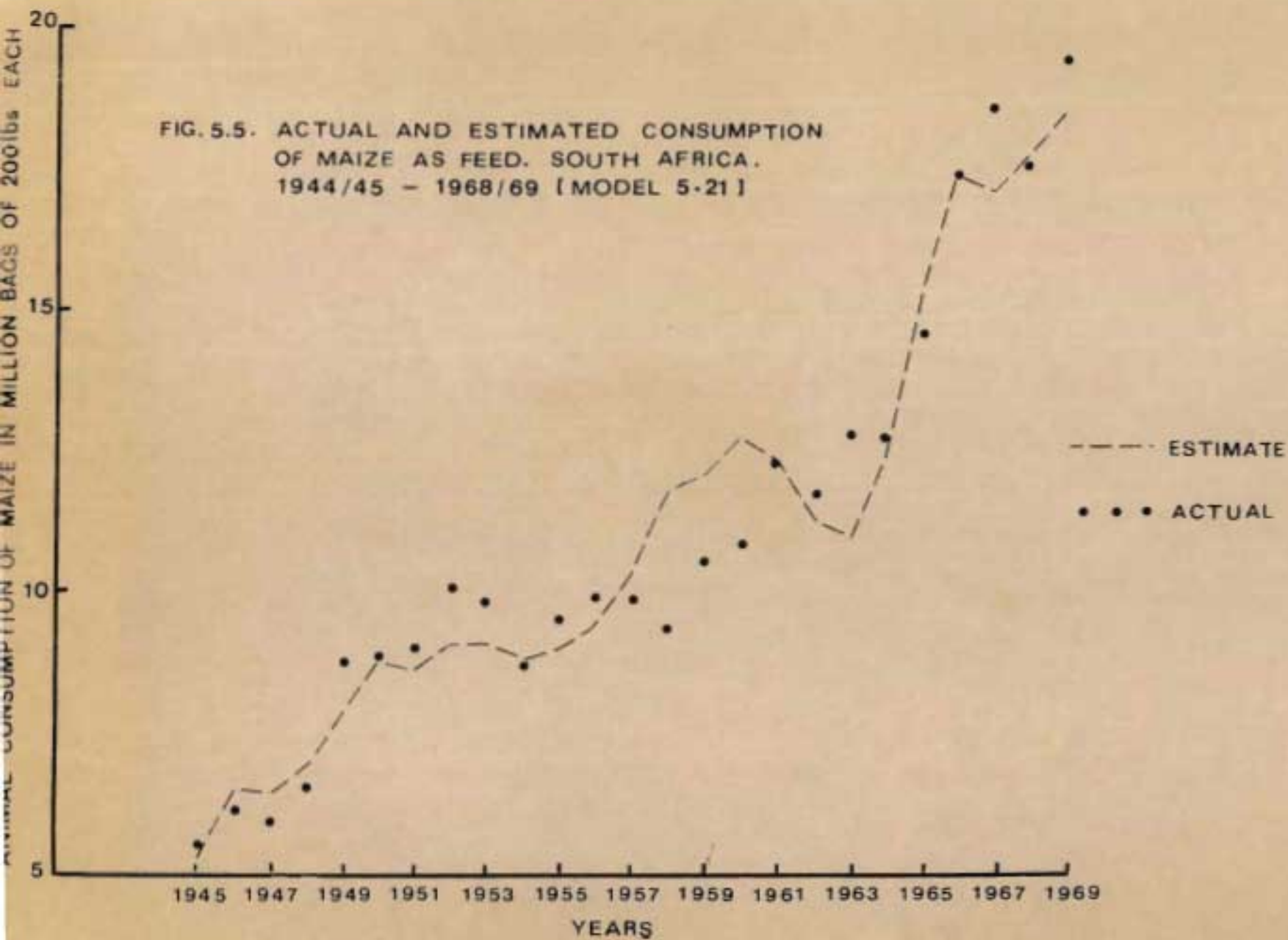
In South Africa opinion in the past has suggested alternative channels through which surplus maize could be disposed. The alternative of utilizing it as feed has been rejected on the grounds that the price gap between feed and livestock products is not wide enough to make this feasible as, for example, in the U.S.A.

These findings may throw some light on the problem. For example, the direction and to some extent the magnitude of the effect of a lower maize price on the grain's utilization as feed can to some extent be calculated. The results of Table 5.4 are optimistic. With a demand elasticity greater than one, total farm income can be increased through a reduction of the price of maize used for feed. The increase in total income to the maize industry does appear to be considerable in the long run when stockfeeders have more time to adjust.

The actual and estimated animal consumption of maize is portrayed in Fig. 5.5. Estimations are based on the retail price of

ANNUAL CONSUMPTION OF MAIZE IN MILLION BAGS OF 200lbs EACH

FIG. 5.5. ACTUAL AND ESTIMATED CONSUMPTION
OF MAIZE AS FEED. SOUTH AFRICA.
1944/45 - 1968/69 [MODEL 5-21]



maize deflated by the producer's price of dairy products and on the livestock inventory (equation 5.21). The model has a fairly close fit which tends to underestimate during 1949-1956 and to overestimate during 1957-1960. The simple correlation between actual and predicted values is .915.

5.4. Demand for fuel and lubricants (provincial model)

As fuel and lubricants are complementary to tractors, trucks and other machinery their demands will also fluctuate with the machinery stock. The demand for fuel can thus be seen as solely dependent on that of machinery. Variables like income and the labour wage rate will consequently affect the demand for fuel through the machinery demand. In the following model the direct effects of these variables are estimated as fuel is considered as another operating input. It may be argued that price and income variables have a larger short term effect on the purchases of fuel than on machinery. With cheaper fuel, which means an increase in real income, the farmer may decide in the short run not to increase his fixed capital stock but rather to push up the operating time of his machines. The price of fuel may also determine the type of machine purchased. If fuel is expensive machines with surplus capacity will not be purchased.

The expenditure on this item in South Africa is considerable and a separate analysis may be justified. The provincial demand for the period 1950-1963, excluding 1951, is presented in the following untransformed model:-

$$Y = 4,616 + 3,797 X_1 - 2,336 X_2 + 3,377 X_3 + 3.591 I + 95.96 P_L - 34.01 F$$

(t=4.87) (t=3.74) (t=7.74) (t=1.85) (t=1.93) (t=2.34)

5.27

$$R^2 = .918$$

$$df = 45$$

Y = Provincial expenditure on fuel and lubricants in thousand rands deflated by its price index. Price index 1947/48-1949/50 = 100.

I = Gross income in million rands deflated by the consumer price index. Price index 1947/48 - 1949/50 = 100.

P_L = Price of land in rands per morgen deflated by the consumer price index. Price index 1947/48 - 1949/50 = 100.

F = Price of fuel deflated by the price of labour 1947/48 - 1949/50=100.

X_1 = 1 if Cape, 0 otherwise;

X_2 = 1 if Natal, 0 otherwise;

X_3 = 1 if Transvaal, 0 otherwise; if $X_1 = X_2 = X_3 = 0$, then Free State.

The price of fuel was deflated in the above model by the price of labour. This implies that an increase in the wage rate relative to prices of fuel and lubricants should lead to greater purchases of lubricants and fuels. Other deflators were also tried but resulted in signs contrary to what can be expected from economic theory.

All the variables have signs in accordance with economic theory. There appears to be a substitution effect between land and fuel as the operating item. With an increase in the cost of land farmers will farm more intensively. With more disposable capital more fuel is also bought. Increasing wages also have a stimulating effect on quantity demanded. As previously pointed out some of these variables may influence the demand for fuel on an indirect basis.

5.5. Demand for hired farm labour

5.5.1. Aggregate demand function

The hypothesis is tested in this section that the demand for farm labour is a function of its own price and other factors. Time series data were used for the period 1949 - 1965. The period 1947/48 - 1949/50 was used as a base for all indexes.

In Table 5.5 elasticities and t values for the independent variables are shown.

Different regression models were used for the following purposes:-

- (a) to examine the effect of the inclusion or non-inclusion of variables assumed to have important effects on the use of farm labour;
- (b) to compare results from variables deflated by different price series;
- (c) to estimate short and long run elasticities by including the quantity of farm labour lagged one period as an additional independent variable.

The price of labour, the farm wage rate, was the principal explanatory variable in each equation in Table 5.5. Inclusion of other variables in the specification of the model caused the values of the coefficients of the original variables to be altered substantially.

The price elasticities of labour deflated respectively by the prices of all farming requisites, machinery prices and machinery and operating input prices have coefficients $-.63$, $-.75$ and $-.77$.*

* These elasticities are of a long run nature because adjustment to price changes is assumed to be instantaneous ($b = 1$).

TABLE 5.5. REGRESSION COEFFICIENTS AND t VALUES (IN PARENTHESES) FOR DEMAND FUNCTIONS OF LABOUR IN SOUTH AFRICA
1949 - 1965

Equation	R^2	d	Constant	$P_L(t)$	T	$Y(t-1)$	P_{LP}	P_{LM}	P_{Lo}	$C(t-1)$	df
5.28 (L)	.878	1.80	7.0245	$-.6303$ ($t = 5.45$)		0.1118 ($t = .60$)					14
5.29 (L)	.830	1.76	5.2716			.2964 ($t = 1.49$)	$-.4379$ ($t = 4.18$)				14
5.30* (L)	.918	1.85	8.342		$-.0048$ ($t = 1.92$)			$-.7498$ ($t = 7.75$)			15
5.31 (L)	.901	1.72	4.5851						$-.7689$ ($t = 9.96$)	.4629 ($t = 1.64$)	14
5.32 (O)	.910	1.85	183.56		$-.4527$ ($t = 2.12$)			$-.5704$ ($t = 7.26$)			15
5.33 (O)	.925	2.22	120.18						$-.5903$ ($t = 11.58$)	$+.0179$ ($t = 1.93$)	14

* Time series data for the period 1948/65 were used. L = Data transformed to logarithms. O = Data in original values.

$Y(t)$ = Index of expenditure at constant prices on farm labour for year t . P_{LM} = Farm wages deflated by an index of machinery prices lagged one year.
 $Y(t)$ is the independent variable and is thus not shown in the table.

$P_L(t)$ = Farm wages deflated by a price index of all farming requisites combined. P_{Lo} = Farm wages deflated by an index of machinery and operating input prices.

P_{LP} = Farm wages deflated by an index of producers' prices.

T = Time measured as the last two digits of a split year.

$C(t)$ = Capital assets at constant prices for year t .

This demonstrates the effect of different deflators upon demand elasticities. These results show that an increase in these input prices corresponds with a decrease in the real wage rate which will result in an increase of quantity of labour demanded. The above-mentioned elasticity coefficients are all significant at the .001% level.

According to the distributed lag model 5.29, the short run elasticity of labour demand is $-.44$ which is significant at the .001% level. The adjustment coefficient is $.704^*$ ($1 - b = .296$) which gives a long run elasticity of $-.63$. This is in line with the estimates of the other equations in which the distributed lag model was not used. The long run price elasticity is consequently greater than the short run elasticity as would be expected. A rise or decline in farm wages relative to prices which farmers receive or to prices they pay for other inputs does not allow an immediate change in the reorganisation of the farm. With a drop in wages time is needed to depreciate out the machines on hand and to switch to more labour intensive enterprises. With an increase in wages time must be allowed for the buying of additional machines and for acquiring capital to buy them.

Heady and Tweeten (76, pp. 194-230) found short run elasticities for the U.S.A. taken at the mean of observations for the 1929-1957 period that ranged from $-.25$ to $-.48$. Their long run elasticities of labour demand at the mean observation for the 1929-1957 period ranged from $-.53$ to $-.60$.

Schuh (118, p. 317) estimated short and long run demand

* This coefficient of adjustment (t value = 1.5) indicates that 70% of the discrepancy between equilibrium and actual employment is eliminated within the first year by the demanders of labour. When this variable is compared with other studies it appears too high.

elasticities of $-.23$ and $-.77$ at the 1957 levels using simultaneous equations.

Griliches (50) estimated short and long run demand elasticities of $-.11$ and $-.62$ at the mean levels for the period 1912-1956, using numbers of labourers as the dependent variable. The elasticities at the 1956 levels from this model were estimated as $-.32$ and -1.7 for the short and long run.

It may be concluded that the price elasticities of farm wages based on this study for South Africa are close to estimates of Heady and Tweeten (76), Griliches (50) and Schuh (118) for the U.S.A. Heady and Tweeten and Schuh also found that the elasticity of labour demand had been increasing over time.

In the lag model 5.29 the wage rate was deflated by an index of producer's prices. This indicates that the demand for labour has been responsive to farm product prices.

The coefficient of the capital assets variable in equation 5.33 is positive, and has a t value of 1.9. This variable indicates the response of the demand for labour to changes in the scale of farming as exemplified by the stock of farm assets. The positive elasticity suggests that as the scale of farming (capital assets) has increased, the number of hired workers has also increased.

The trend variables in equations 5.30 and 5.32 have t values of approximately two. As this variable has no justification in economic theory, it was omitted from the other equations. Because of the inclusion of the trend in models 5.30 and 5.32, these models are, strictly speaking, not static anymore. The trend variable, however, can be viewed, not as a specific dynamic assumption, but rather as an attempt to pick up the effects of omitted variables that are highly

correlated with time. There appears no substantial difference in explained portion between the transformed and untransformed models.

The assumption that wages can be treated as exogenous is not tenable and the simultaneous equation technique is probably more appropriate.

5.5.2. Provincial model for Bantu regular labour

The regional model relates to the period 1946 - 1963 excluding the years 1948, 1949 and 1951 because data were not available during these years. Equation 5.34 is estimated in the original form.

$$Y_t = 160,688 + 94,227 X_1 + 179,240 X_2 - 2,510.3 P + 1.851 Tr$$

$$(t=10.90) \quad (t=22.31) \quad (t=6.01) \quad (t=8.93) \quad 5.34$$

$$R^2 = .976$$

$$df = 34$$

Y_t = Regular Bantu labour on farms.

P = Wage rate of Bantu regular labour in rands deflated by the index of prices of other farm inputs. Base period for other input prices 1947/48 - 1949/50 = 100.

Tr = Number of tractors on farms.

X_1 = 1 if Natal, 0 otherwise;

X_2 = 1 if Transvaal, 0 otherwise; if $X_1 = 0$, $X_2 = 0$, then Free State.

A 1% increase in the real wage is estimated to release .51% Bantu workers from the agricultural sector. There also appears to exist a complementary relationship between labour and tractors. An increase in tractor numbers of 1% is estimated to increase the demand for labour by .18%. Tractor numbers may be considered as a reasonably reliable index of machinery stock. The question as to whether

machinery can be regarded as being a substitute or complement for labour is interesting and debatable. Some machines like tractors replace draught animals while others replace labour. Tractors are, however, seen in this context as representing the mechanisation process and not as an individual item. It appears that in South Africa the stage has not been reached where mechanisation replaces labour. The reason can be seen in the fact that in South Africa the Bantu wage rate relative to prices of other resources has not increased but in fact decreased from 1946 to 1963. Farmers consequently do not find it economically profitable to substitute labour with capital items. On the contrary, the greater mechanisation has increased the value of the marginal product of labour.

Data on the Cape Province were dropped from the model as the labour numbers in this Province could not be explained by the same economic variables that explained labour demand in the other Provinces. This may be attributed to the policy of the government to reserve the greater part of the Cape for the Coloureds. There was for the period under consideration a gradual labour build up in the Transvaal, Natal and the Free State to approximately 1956. Since then labour numbers have declined slightly.

Regional models for White and Coloured regular labour, and White, Bantu and Coloured domestic servants were disappointing, and will not be discussed. These labourers, however, constitute a small proportion of the hired labour force.

CHAPTER 6.

RESOURCE DEMAND FOR FARM MACHINERY6.1. Some theoretical aspects of investment

Investment and demand are here considered as synonymous, the demand for fixed capital being an investment decision. The farmer is continually confronted with investment decisions. The capital stock of farmers in relationship to output, is high in comparison with the other industries. Franzsen and Willers show capital-output ratios based on all capital stock and measured by the ratio of reproducible real capital stock to real domestic income, for the agricultural, mining, manufacturing and all sectors, for the period 1944 to 1955 of 3.5, 2.0, 1.6 and 2.6 (10, p. 145).

An attempt to analyse the complex system of decision-making in the field of investment will be a step towards an understanding of farm problems because disagreement still exists among economists and the theory and empirical findings of research workers on investment bear further examination. Literature on the micro-economic aspect of investment is plentiful, but by no means sophisticated.

Some of the more important variables in making investment decisions will now be discussed.

6.1.1. Income

In his theory of output determination for the economy as a whole, Keynes treats investment simply as an independent variable. In his more elaborate "marginal efficiency of capital" theory, Keynes analyses investment activities as a function of the expected profit and interest rate (93, p. 44).

According to Keynes, investment may be further divided into

autonomous and induced investment. Autonomous investment is not dependent on the level of income, as, for example, investment in the Orange River Scheme. Induced investment can be regarded as a function of the level of income. In this context the term marginal propensity to invest is used, measuring the rate of change of investment as income changes.

Several studies cited by Kuh (91) show profit to be an important factor determining investment. Profit theorists contend that, since entrepreneurs should maximise the present value of expected future profits through investment activity, they will invest according to present profits because these closely reflect future profits (92). Eisner (35, p. 386) found the coefficients of the profit variables to be uniformly low in cross sections, but relatively high in time series analysis. Firms in his study made capital expenditures in the period immediately following higher profits, but firms earning higher profits did not make markedly greater capital expenditures than firms earning lower profits. Past profits may thus play a rôle in the timing of capital expenditures but they do not affect its long run average.

Grunfeld (65, pp. 211-266) states that the market value of the firm predicts investment, better than profit. Grunfeld concludes that the rôle of profits is probably that of a surrogate variable, in that it tends to be correlated with some of the main forces causing changes in investment and therefore with investment as well.

Griliches (53) in his demand for farm tractors, omitted income because he argued that "...in the conventional theory of the firm the firm has no budget restraint, and the production function is the only constraint." Simultaneous equation bias may arise when income is used as an explanatory variable. Income may not only determine

investment but investment can also determine income as described by the multiplier-accelerator approach. This may not be as serious in agricultural investment models as in industrial models.

The argument for inclusion of net income in the investment function is strong according to Haddy and Tweeten (76). Firstly, because it is an indication of the returns from the durable resource. Secondly, net farm income is an important indication of the future ability of the farmer to pay for the asset. The farmer may hesitate to invest unless he feels sure about future earning potential and external credit availability is often determined by the ability to pay for the loan.

It is also a common practice for farmers in South Africa to accumulate capital assets during years of prosperity to lessen their income tax burden.

6.1.2. Interest rate

The extent to which investment depends on the rate of interest is still a debatable topic. It may be argued that the interest rate will not be important in making investment decisions if the period over which the discounting of future yields of an asset is relatively short.

Several endogenous and exogenous factors, some of which are not measurable (93, p. 61), may however shift the investment schedule. Some of the variables will be taken into account in subsequent sections like the level of income and existing stock of capital.

Certain shift factors like wars can be incorporated in the investment functions by using dummy variables. By incorporating a trend variable, factors like inventions and innovations can to some

extent be accounted for. In the empirical investment demand functions estimated in this study, prices of products were built into the model which may also be considered as a measurement of consumer demand.

However, inability to estimate the partial effect of interest rate on investment may be the result of an inadequate measurement of any of these shift parameters. The Keynesian approach is that changes in monetary policy affect interest rates and that the interest rate in turn affects the level of investment. Hamburger (63, pp. 1131-1153) found a more direct link between monetary operations and consumer expenditures on durable goods.

Two studies made on the basis of questionnaires submitted to a large sample of businessmen by the Oxford Economists' Research Group and by a Harvard Business School investigator "show conclusively that the interest rate is largely neglected when investment decisions are being made." (103, pp. 96-106). Most of the people who said that the cost of capital had no effect on investment in the Oxford study, did so on the grounds that they relied on self financing, or because interest is so small an element in comparison with depreciation or because of the uncertainty of the product market. It is obvious that if the internal rate of return of an investment greatly exceeds the interest rate, considering risks and uncertainty, then the prevailing interest rate will not affect the investment decision.

6.1.3. Other assets

In his secular statements, Keynes (93) makes investment also dependent on capital accumulation.

The stock of other assets may be an indication of the ability of the farmer to pay for new capital items or to borrow funds for this

purpose. Other assets may be complements or substitutes affecting the marginal product of the purchased item. Grunfeld (65) measures the value of a firm (in industry) by summing up the market value of all outstanding shares and the book value of all debt outstanding. Other assets are to some degree an indication of the market value of the firm as used by Grunfeld (65). This writer concludes that the market value of the firm and stock of plant and equipment move together with investment expenditure over time. He observed, in particular, that the value of the firm tends to rise in years preceding troughs in investment and to fall in years preceding peaks, thus in a sense predicting peaks and troughs.

Capital assets increase during periods of inflation and these capital gains may serve as a source of equity and funds for investment. Liabilities are usually fixed obligations like loans that are thus unaffected by inflation. Hedy and Tweeten (76) point out that during years of prosperity farmers can pay their debts and build their equity, consequently the ratio of equity to liabilities may be used as a proxy variable for past income.

6.1.4. Prices of inputs

Assuming competitive product and factor markets, the demand for an input also depends on the price of the input, the price of the product and prices of other inputs.

In this study the demand function is assumed to be homogeneous of degree zero. The doubling of all prices will not affect the level of investment. The prices may be entered as ratios into the model, the variables are reduced by one, and account is taken of the price deflation problem.

Even considering earning power, income and other factors, the decision to buy a particular input will depend on its relative price or the farmer's belief that it is relatively high or low.

6.1.5. The acceleration principle

The acceleration principle as applied to induced investment in a single firm may be stated rigorously as (89, p. 116):

$$K_t - K_{t-1} = a [O_t - O_{t-1}]$$

K_t = Firm's stock of capital equipment in year t ;

O_t = Firm's final output in year t ;

a = Accelerator.

Knox (1966) concludes, using the acceleration principle in his analysis, that "from the moment at which least cost output is passed there is a possibility of investment; but there is no knowing just when the decision to invest will be taken" (89, pp. 114-133). This may be a useful tool in analysing firm (or farm) behaviour, but it does not contribute in explaining the aggregate behaviour of an industry.

A basic postulate of accelerator theory is that the firm's capital/output ratio may be so firmly established that an increase in the demand for the product may increase the demand for capital stocks. This will only be the case if no surplus capacity exists. Therefore, a necessary assumption for the acceleration principle is that firms should be operating at full capacity. Franzsen and Willers show capital/output ratios for different sectors for the period 1919-1955 which had remained relatively stable. The capital/output ratios for agriculture based on fixed capital are 2.3 for 1919-1928 and 2.1 for 1944-1955 (10, p. 145).

In trade cycle theories, income is made dependent on investment via the multiplier and investment on income, through profit expectations via the accelerator. Investment is dependent not on the level of income but on the rate of change of income (84).

6.1.6. The residual funds, echo effect and senility effect theories of investment

The echo effect states that the older the existing stock of capital, the greater the replacement demand (100). Einarssen, however, found a low correlation between the age of a firm's assets and its propensity to invest (100).

The senility effect suggests that a firm which tends to hold old capital stocks over long periods will resist any change in the age composition of its stocks in the future (100). It is well known that certain farmers, regions or sectors adopt modern technology at a faster rate than others.

The residual funds theory claims that firms rely on internal funds as the source of investment rather than on capital from outside sources.

6.1.7. The Investment Model

According to Griliches (53) it is the "stock of machines that enters the production function as an input, not the annual purchases of new machines." Hence, he concludes that the investment function for new purchases must be derived from the demand for the stock. Hedy and Tweeten (76) maintain that the variable manipulated by farmers to achieve the proper level of stock is annual purchases and consequently they used the annual investment as the dependent variable. Minden (101, p. 79) also preferred to use

annual purchases rather than stock levels as the dependent variables.

In the present study preference was given to a flow demand equation using annual investment because of the dependence of the stock level on the depreciation rate. The Division of Agricultural Marketing Research in Pretoria computes stocks (aggregate value) by assuming specific depreciation charges for different assets. This depreciation is not necessarily a true reflection of the value of these assets to the farmer and may cause an imputed over- or under-estimation effect on stock levels. However, in the case of farm tractors and trucks the stock variable, total number of farm tractors and trucks, was used. The same depreciation problem does not exist in this case. It was, however, necessary to assume that (say) a three year old tractor can do the same work as a one year old tractor. At any point in time great differences in quality exist among durable items. Also, over time, the quality changes in the durable sector are much greater than in any other sector (65). In contrast, products such as a pound of beef or a bag of maize, are standardised commodities for any point in time, or period of time. Price data for durable items also do not allow for quality changes. The price of a durable item is a weighted price of different sizes of this item, introducing a certain amount of bias into the data. When a flow demand is estimated, instead of measuring the stock of durable assets, ~~then~~ the influence which the existing stock has on the rate of purchases is ignored. New purchases of a durable item in a given period, will be lower, the higher the level of services obtainable from the existing stock carried into the period.

According to Harberger (65), if cars of all ages have the same service yield, the aggregate service yield of the existing

stock of cars would be measured by their numbers. If the service yield of individual cars is proportional to their value, the service yield of the stock would be measured by its aggregate value. Since cars tend to depreciate by a constant percentage of their value each year the "aggregate value" appears to be a more appropriate measure. In this study the "aggregate value" data were found to be unreliable and they were consequently not used. Apart from having to assume a certain depreciation pattern the maintenance costs, taxes and interest charges may also be different for different durable items. Maintenance costs can also substitute for new purchases. From this discussion it is clear that no ideal measure exists to capture the services from durable items. In practice the researcher must rely on available data and often, as in the case of this study, is not given a choice of alternative data series.

Harberger (65, p. 6) says that demand studies for durable items "do not attempt to achieve precise and unequivocal estimates", these studies must be considered as an "effort to answer rather broad questions". The studies reported in this thesis, in fact all econometric research, can be seen in the spirit of this statement.

With a total fixed investment in South African agriculture of more than R6,000 m (31, p. 86) the effect of multipliers and accelerators can probably not be completely ruled out. Mirakhor and Orazem showed that \$1.00 of farm income in Kansas generated \$3.33 of income in the whole economy, whereas \$1.00 of non-farm income generated only \$1.46 of total income (102). In South Africa economists are generally aware of the inflationary effects of a good maize or other major crop.

Single equation investment functions are used throughout the study as it is believed that current prices are predetermined in the non-farm sector. It is thus assumed that the supply of farm machinery is highly elastic and that the supply and demand functions of machinery need not be estimated simultaneously.

The statistical resource demand model which was used in Chapter 5 will be fitted in this chapter (see equation 5.1 for explanation).

6.2. Demand functions for farm tractors

6.2.1. Aggregate model

A lag demand model for farm tractors for the period 1950 to 1964 is specified in equation 6.1 where the original values were transformed to logarithms.

$$Y_t = +4.8419 - .3812 P + .7340 Y_{(t-1)} \quad 6.1.$$

(t=5.54) (t=28.18)

$$R^2 = .998$$

$$d = 2.48$$

$$df = 10$$

Y_t = Number of farm tractors for the current year.

P = Price of farm tractors deflated by the price of all farm labour (1954 = 100).

In alternative models, the price of tractors was deflated by the price of crops and the price of all farm requisites, but the price elasticity of farm tractors turned out non-significant and the models are consequently not reported.

Both the price and the lag number of tractor variables are highly significant, and explain for all practical purposes 100% of

the total variation in tractor numbers. The low degrees of freedom cast some doubt on the reliability of these estimates.

The short run price elasticity of tractors is $-.38$ which is relatively low. The adjustment coefficient is $b = 1 - .734 = .266$, indicating that 27% of the adjustment to an equilibrium level will occur in the first year after the displacement took place. The long run price elasticity of tractors is -1.43 , indicating an elastic long run demand compared with the inelastic short run demand. These results are very close to that of Griliches (53, pp. 181-207) for the U.S.A. Griliches found a short run elasticity of $-.25$ and a long run elasticity of -1.5 . Because tractor prices are deflated by an index of farm wages, a 1% change in tractor prices is assumed to have the same percentage effect on tractor numbers as a 1% change in the wage rate. The elasticity of this "real" tractor price is negative according to model 6.1 implying that a decrease in tractor prices or an increase in the wage rate will stimulate the quantity taken by buyers.

From the assumption that adjustment is instantaneous, the following model in original form was tested:

$$Y = 270,039 - 2,168.1 P + .087997 I_{(t-1)} \quad 6.2.$$

(t=9.56) (t=1.24)

$$R^2 = .954$$

$$d = 1.45$$

$$df = 10$$

$I_{(t-1)}$ = Cash income, in thousand rands, deflated by prices of farm inputs including labour, lagged one year. (Price index 1947/48 - 1949/50 = 100).

Variables Y and P are the same as in model 6.1.

By imposing an adjustment coefficient of "1" on the data, the R^2 is decreased as in equation 6.2.

The income variable is positive with a t value that is greater than 1. The price of tractor variable is highly significant. From models 6.1 and 6.2 it may be concluded that the cash income of farmers lagged one year has little effect on the purchases of farm tractors.

No economic model can be considered to be unique and the only model to explain economic data. For this reason the models should supplement each other and not be seen as contradictory. Comparing the two models, 6.1 appears to be superior. Griliches (57, pp. 33, 34) shows that if the true equation is $Y_t = aX_t + U_t$ where the errors are serially correlated $U_t = rU_{t-1} + e_t$, but $Y_t = aX_t + bY_{t-1} + V_t$ is estimated, then the coefficients in the latter model may be significant and the serial correlation may be reduced by the introduction of the lagged dependent variable. Thus the partial adjustment model may work even though it is wrong. In this case the true equation can be written as $Y_t = aX_t + bY_{t-1} + abX_{t-1} + e_t$. In the above models U_t , V_t and e_t are the error components. This hypothesis is tested in the following serial correlation model:

$$Y_t = 4.899 - .4039 P_t + .7303 Y_{t-1} + .0194 P_{t-1}$$

$$(t=3.06) \quad (t=23.06) \quad (t=.162)$$

$$R^2 = .998$$

$$df = 9$$

where the variables are transformed to logarithms. The lagged price of tractors is not significant which leads to the acceptance of the

partial adjustment model 6.1 and the rejection of the serial correlated model. From this it appears as if the coefficients of the partial adjustment model are significant and sensible "for the right reasons".

6.2.2. Provincial model

In an attempt to increase the degrees of freedom, a model based on cross sectional and time series data combined was constructed for the period 1950 - 1962, excluding 1951 and 1952, because census figures of tractor numbers were not available. Model 6.3. was run in original values.

$$Y_t = -9,546 + 15,486 X_1 - 4,380 X_2 + 14,238 X_3 + 39.27 I_t + 537.9 P_{Lt} \\ (t=3.78) \quad (t=1.02) \quad (t=5.37) \quad (t=3.36) \quad (t=2.02) \\ 6.3.$$

$$- 232.7 P_T + 212.1 P_{LC} \\ (t=2.79) \quad (t=2.02)$$

$$R^2 = .914$$

$$df = 36$$

Y_t = Tractor numbers in the provinces.

X_1 = 1 if Cape, 0 otherwise;

X_2 = 1 if Natal, 0 otherwise;

X_3 = 1 if Transvaal, 0 otherwise; if $X_1 = 0$, $X_2 = 0$, $X_3 = 0$, then
Free State.

I_t = Gross income from main crops in million rands on a provincial basis deflated by the consumer price index. Price index 1947/48 - 1949/50 = 100).

P_{Lt} = Price of land per morgen on a provincial basis deflated by consumer price index. Price index 1947/48 - 1949/50 = 100).

P_T = Price of tractors deflated by a weighted wage of White, Bantu

and Coloured regular labour on a provincial basis. (1947 and 1950 = 100).

P_{LC} = Price of livestock deflated by the price of crops on a provincial basis (1947/48 - 1949/50 = 100).

With the aid of model 6.3 an estimate of tractor numbers at a particular point in time for any of the four provinces can be made by substituting the relevant income and price variables. For example, to estimate tractor numbers in the Transvaal, X_1 and X_2 are equated to zero, and X_3 to $\frac{1}{2}$. To make an estimate of tractor numbers in the Orange Free State, $X_1 = 0$, $X_2 = 0$ and $X_3 = 0$.

Model 6.3 is a stock demand model because the total number or stock of tractors is used as the dependent variable.

More than 90% of the provincial stock numbers of tractors is explained by income, price of land, price of tractors, dummy variables and the livestock crop price ratio. All variables have coefficients greater than their standard errors and the equation appears to be satisfactory both from an economic and a statistical point of view.

The tractor price elasticity is $-.96$ at the mean levels for all four provinces and this is significant at the $.01$ level. As the short and long run elasticities are forced to be the same, this elasticity can be expected to be somewhere between the long and short run, which in fact is the case. Compare the price elasticity of $-.96$ derived from model 6.3 with the long and short run elasticities respectively of -1.43 and $-.38$ of model 6.1.

The income elasticity is $.66$ which is significant at the 1% level and numerically smaller than the price elasticity. This suggests that farmers will react more to a 1% price change of tractors

than to a 1% change in income. The gross income variable was used because a net income variable could not be computed. However, by using gross income which is the same as aggregate output, as a variable, the demand function may be seen as transformed into a capacity model. The significance of the aggregate output variable indicates that investment is proportional to the positive rate of change in output and not influenced by the expected earning power of the increased output. Models using capacity theories have been successful in both agricultural and non-agricultural investment studies (119, pp. 184-198), (92), (46, pp. 338-357).

The price of livestock deflated by the price of crop variable is positive which could mean that the livestock price variable was the more important decision variable (101, p. 135). Minden (101), finding the same result, attributed this to the fact that crop prices are influenced by numerous exogenous influences such as government farm programmes and the international trade situation, whereas livestock prices are less influenced by exogenous forces. This applies also to South Africa where prices are arbitrarily fixed for products like maize and winter cereals which fall under the one channel fixed price schemes. The prices of livestock products are determined on the open market except in the case of industrial milk and cream for butter, which fall under the above-mentioned scheme. Fresh milk and cream fall under the one channel pool schemes. The Control Boards may support the prices of meat and other crops under the surplus removal scheme (24). Only a small percentage of cash crops is marketed through livestock in South Africa which may cast some doubt on the positive sign of the livestock to crop variable. This could also mean the greater use of

machinery for producing forage crops which is an important part of crop production.

According to the above model, tractors and land are substitutes. To some extent tractors and land may be either substitutes or complements.

The t values of the dummy variables in the model show that their introduction was necessary.

If tractors do not deteriorate much with age, then the demand for capital as a productive asset is a demand for the number of machines. It is consequently assumed, for example, that a four year old tractor can do the same work as a new tractor. This appears to be a realistic assumption for all practical purposes. Griliches (53, pp. 181-207) pointed out that "it is the stock of machines (tractors) that enters the production function as an input, not the annual purchases of new machines. Hence the 'investment function', the demand function for new purchases, must be derived from the stock." Other methods of measuring the demand like the expenditure on new tractors or machinery may be more undesirable. To derive the quantity demanded in real terms the expenditure data must be deflated by the price of the input. Griliches (49), Tweeten (132), Minden (101), and others deflated the quantity demanded in this way. It was also adopted in the present study. The writer, however, thinks that by deflating the dependent variable by the numerator of one of the independent variables some kind of built-in dependence in the model may result. He also considers this to be more serious when data are not reliable and because of this, he has as far as possible relied on actual census data and not on interpolations. Interpolations

between two benchmarks one year apart* was considered to be in order for stock numbers because it is the desired stock that is demanded and not the actual stock.

Griliches (53) found that (for the U.S.A.) the price ratio of tractors to crops was significant, whereas that of tractors to labour was not. In this study the price ratio of tractors to labour was significant but not the price ratio of tractors to crops (not presented). Rayner and Cowling (111) arrived at a result for the United Kingdom similar to that of the present study for South Africa. An argument used to explain the contradictory results between the U.K. and U.S.A. was the greater importance of hired labour in United Kingdom agriculture with labour costs forming a much higher proportion of total production costs in the U.K. than in the U.S.A. This argument may also be used as an explanation of the results arrived at in the study for South Africa.

It may be argued that the actual substitution was between tractors and draught animals and not between tractors and labour. It was, however, not possible to test this hypothesis because of the lack of census data on draught animals. Griliches (53, p. 194) found for the U.S.A. "that changes in the stock of horses and mules had very little impact on the demand for tractors." The coefficient of this variable was not significantly different from zero in his models. The writer views this substituting relationship, not so much as a substitution between tractors and labour, but rather as a substitution between labour and the mechanisation process.

* For example making an estimate for 1951 when census figures for 1950 and 1952 are available.

6.3. Demand functions for new machinery, implements and tractors
(aggregate model)

Because more data were available on the aggregate demand of new machinery, implements and tractors than on the separate demand, the former was also investigated. At the outset it may be reasoned that individual demand equations should explain the stock or purchases of this aggregate variable much better, due to differences in individual price movements and other factors.

Equation 6.4 represents a demand model in the original form for the aggregate source, namely new machinery, implements and tractors for the period from 1946 to 1963.

$$Y = + 58,492 - 1,108.6 P_M + 293.5 P_{NC} + 356.0 P_r + 395.6 T$$

(t=3.19) (t=0.82) (t=1.72) (t=0.90) 6.4.

$$R^2 = .824$$

$$df = 13$$

$$d = 1.12$$

Y = Value of new machinery, implements and tractors in thousand rands at 1947/48 - 1949/50 prices.

P_M = Weighted price of machinery, implements and tractors for the current year deflated by the price of crops (1947/48 - 1949/50 = 100).

P_{NC} = Price of non-capital inputs for the current year deflated by the wholesale price index. The item, non-capital goods, includes fuel, fertilizers, farm feeds, packing material, dips and sprays, spare parts and repair charges. (1947/48 - 1949/50 = 100).

P_r = The parity ratio; price of product/price of factor. This variable is the ratio of prices received by farmers for

products sold relative to prices paid by farmers for production factors. (1947/48 - 1949/50 = 100).

T = Time.

The price of machinery, implements and tractors was significant at the .005 level. This was more significant than any of the other variables.

The product relative to factor price variable had the expected sign and was significant at the .10 level. Thus an increase in product price, ceteris paribus, will increase purchases of machinery. This may be due to

- (1) improvement in the relative position of the farmer;
 - (2) the farmer may feel more optimistic because of the product price increase, and reason that he can afford to spend more.
- An increase in prices of all factors resulting in a more unfavourable parity ratio will have the opposite effect on the farmer.

A positive sign of the real price of non-capital factors indicates a substitution effect between these factors and aggregate machinery. This variable however was not significant.

The time trend had a t value of less than one and so did not contribute much in explaining the variability in the dependent variable.

6.4. Demand functions for new machinery and implements

6.4.1. Aggregate model

The least squares estimating equations of the demand for new machinery and implements are presented in Table 6.1 for the period 1954 - 1968. All variables were transformed to Naperian logarithms, except the time variable which is in original values.

TABLE 6.1. DEMAND (ANNUAL GROSS INVESTMENT) FOR ALL FARM MACHINERY AND IMPLEMENTS IN SOUTH AFRICA. 1954 TO 1968.

Equation	R ²	d	Constant	P _t	P _{t-1}	P _{NC}	T	df
6.5	.704	2.12	17.7911		-1.7660 (t=4.85)		-.0074 (t=1.61)	12
6.6	.536	1.17	18.1926	-1.548 (t=2.14)		-.4275 (t=.19)		12
6.7	.837	2.37	19.2183	-1.965 (t=7.26)			-.0161 (t=4.60)	12

Y = Value of new machinery and implements (in thousand rands) purchased for farm use at 1947/48 - 1949/50 prices.

P_t = Price of machinery and implements deflated by the price of crops for year t. (1947/48 - 1949/50 = 100).

P_{NC} = Price of non-capital goods for period t deflated by the wholesale price index. The item, non-capital goods, includes fuel, fertilizers, farm feeds, packing material, dips and sprays, spare parts and repair charges. (1947/48 - 1949/50 = 100).

T = Time measured as the last two digits of the current year, taking 54 for 1954, etc.

The elasticities of demand at the current year's price (equation 6.7) and last year's price (equation 6.5) were both significant at the .001 level.

The price elasticity of the demand for new machinery and implements is according to Table 6.1 approximately -1.8. For equation 6.5 most (64%) of the variation in purchases of new machinery was explained by lagged machinery prices and only an additional six percent was

explained by introducing the time variable.

The non-capital goods variable is not significant but the negative sign indicates a complementary effect between this variable and machinery purchases. It is an obvious result because an increase in (say) fuel prices will reduce the purchases of certain farm machinery. On the other hand, many non-capital production factors will substitute for farm machinery and consequently result in a positive coefficient.

Several other variables were also tried in alternative models but without any success. This failure may also be attributed to intercorrelations with other independent variables and inadequate degrees of freedom.

The time variable is significant in both equations 6.5 and 6.7. This could also be correlated with other relevant variables which have been omitted from the models. The fact that the time variable was negative may be attributed to the consolidation of farms during the period. Farm consolidation may cause a reduction in the overall machinery input because of more efficient use of the resource or due to surplus capacity on farms before consolidation. This process may be highly correlated with time. It was shown in Table 3.11 of Chapter 3 that farms over 1,714 hectares increased from 10,955 in 1930 and 11,881 in 1955, to 13,175 in 1962.

6.4.2. Provincial model

A regional untransformed model was fitted for the years 1954 - 1963.

$$Y_t = 5,564 + 1,104 X_1 - 1,153 X_2 + 684 X_3 - 374.7 R - 12.19 P_M(t-1)$$

$(t=6.81) \quad (t=5.70) \quad (t=5.78) \quad (t=1.45) \quad (t=1.50)$

6.8.

$R^2 = .940$

$df = 30$

- Y_t = Provincial expenditure in thousand rands on new machinery, vehicles and loose tools deflated by its price index.
1947/48 - 1949/50 = 100.
- R = First mortgage bond interest rate for the current year.
- $P_{M(t-1)}$ = Price of machinery deflated by the provincial crop price index and lagged one year. Price index 1947/48 - 1949/50 = 100).
- X_1 = 1 if Cape, 0 otherwise;
- X_2 = 1 if Natal, 0 otherwise;
- X_3 = 1 if Transvaal, 0 otherwise; if $X_1 = X_2 = X_3 = 0$, then Free State.

The farm mortgage rate has a coefficient greater than its standard error and the expected sign according to economic theory. A decrease of 1% in the mortgage rate is expected to increase machinery purchases by 1.38% which is relatively elastic. Griliches (53) estimated the interest elasticity of the demand for tractors as -1.0 in the short and -5.8 in the long run. He also explains the demand for tractors as solely a function of the price of tractors deflated by the price of crops and the farm mortgage rate. The demand of a durable input, in this case farm machinery, is according to the theory of the firm also dependent on the rate of interest.

A 1% increase in machine prices relative to crop prices is estimated to reduce quantity demanded in the following year by .86% at the mean level for the four provinces. The elasticities of interest rates were consequently estimated as greater than the price elasticity. Harberger (65, p. 14) points out that since interest is only a small fraction of the total imputed cost, the interest elasticity can be expected to be smaller than the price elasticity.

Yet Griliches (65, p. 193) estimated the interest elasticity as approximately five times greater than the price elasticity for farm tractors. He attributes this partly to the sluggishness of the farm mortgage interest rate series used, underestimating the real variability in the marginal rates of interest.

The dummy variables are highly significant and the factor demand functions are at four definite planes, one for every province.

6.5. Demand functions for lorries

6.5.1. Aggregate model

The model 6.9 represents a demand function in a logarithmic transformed form for lorries covering the years 1922 - 1964, excluding the war years 1936 - 1944.* The data for these years were omitted after an examination of prices and incomes for these years.

If prices of lorries are determined independently from farm purchases, then their demand can be estimated from a single equation.

$$Y_t = -0.3403 - .3423 P_t + .6646 Y_{t-1} + .7898 I_t \quad 6.9$$

(t=1.04) (t=5.83) (t=2.71)

$$R^2 = .945$$

$$d = 1.586$$

$$df = 31$$

Y_t = Number of new registrations of lorries by the Agricultural Industry in period t. (Calendar year).

P_t = Price of lorries deflated by the price of crops on a calendar year basis. (1950 = 100).

I_t = Gross value of Agricultural production (in million rands) at

* The model was re-run in terms of original values. The R^2 however dropped to .92 and the t values also showed a substantial decrease.

1947-48 to 1949-50 constant prices. This income variable was lagged six months because the real income of the split year (example 1947-48 corresponds to the period June 1947 until July 1948) was regressed on new purchases of the current year. (In this example 1948).

The distributed lag model was used in the above equation.

The adjustment coefficient is $b = .34$ because $1 - b = .66$. This indicates that the disequilibrium due to price and income changes is not eliminated all at once but 34% of the indicated adjustment is completed in the first year. The elasticity of demand with respect to the real price of lorries is $-.34$ in the short run and $\frac{-.34}{.34} = -1.0$ in the long run. The long run price elasticity is substantially higher than the short run elasticity.

According to equation 6.9, the short run income elasticity is equal to $+.79$ and the long run income elasticity is equal to $\frac{+.79}{.34} = 2.32$. Thus a 1% increase in farm income for a specific year will cause .79% increase in the purchases of new trucks for that same year. The total effect of this increase in income will be to increase purchases by 2.32%. In model 6.9 it was assumed that the same amount of lag is present in the income and price variables. If this is not the case the long run coefficients will be biased.

The price ratio of lorries to crops and the quantity ratio of lorry numbers to agricultural production are portrayed in Fig. 6.1. The two graphs appear to be symmetrical in nature, particularly before World War II. Since World War II price ratios have remained relatively stable but quantity ratios experienced great fluctuations.

Fig. 6.2 shows the actual and estimated values of farm trucks.

INDEX (1947/48 - 49/50 = 100)

FIG. 6.1. QUANTITY AND PRICE RATIOS OF FARM
OUTPUT AND LORRIES PURCHASED FOR
FARM USE, 1922 - 1964.

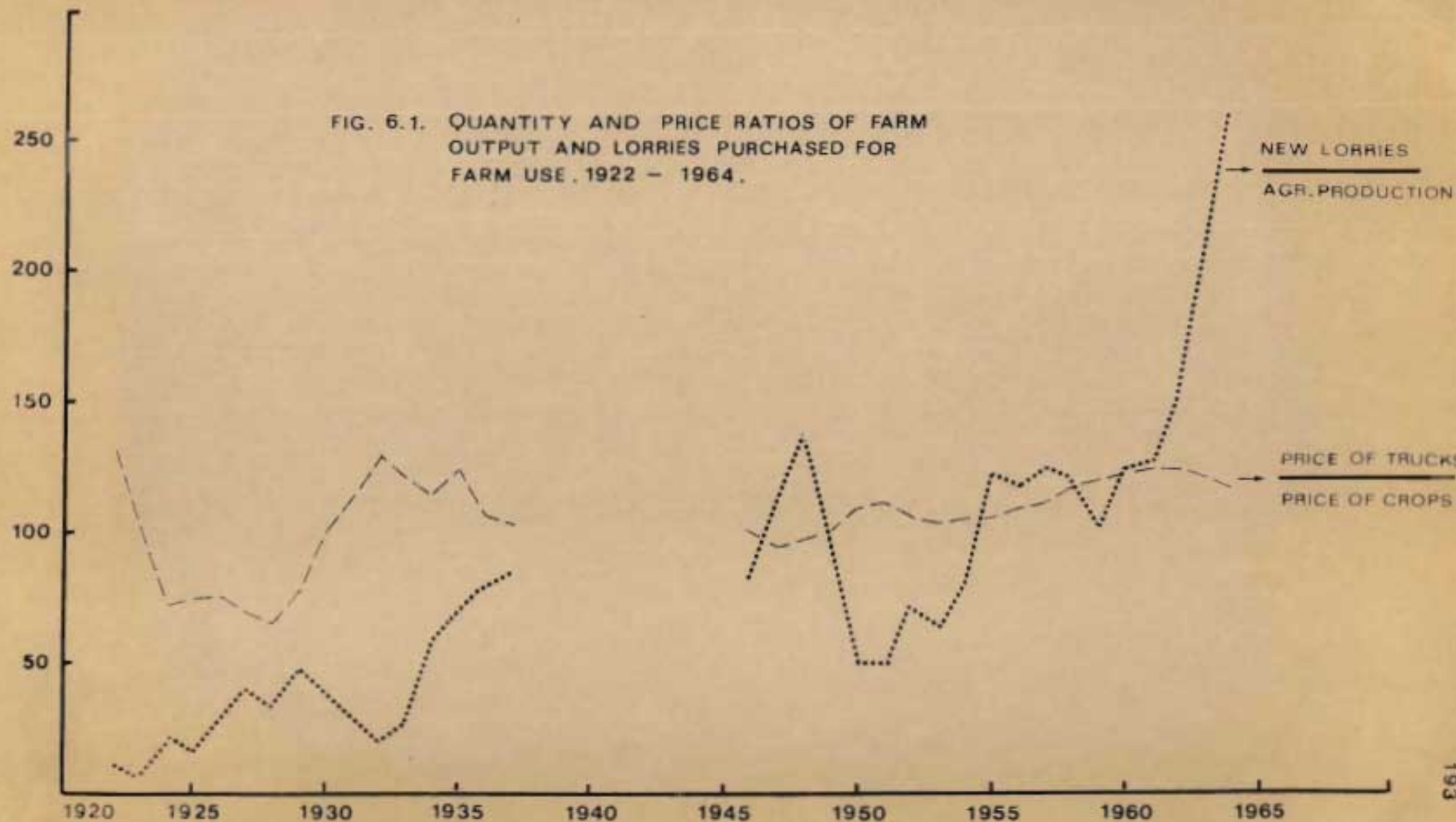


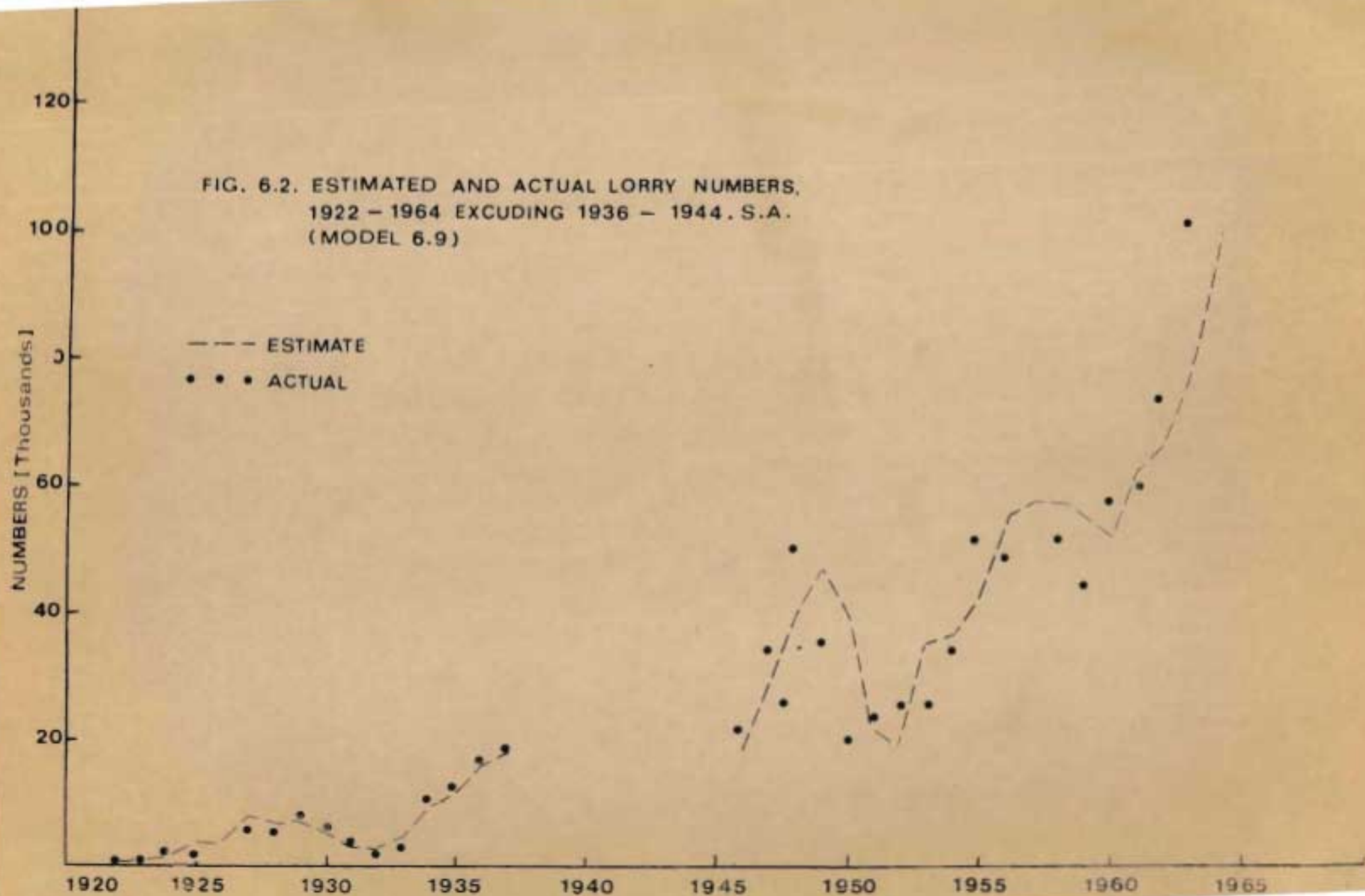
FIG. 6.2. ESTIMATED AND ACTUAL LORRY NUMBERS,
1922 - 1964 EXCLUDING 1936 - 1944. S.A.
(MODEL 6.9)

NUMBERS [Thousands]

--- ESTIMATE
• • • ACTUAL

1920 1925 1930 1935 1940 1945 1950 1955 1960 1965

194



The model appears to estimate the number of new registrations well over the period analysed, although some tendency exists for this function to underestimate purchases in recent years.

6.5.2. Provincial model

The regional model was constructed on original data for the period 1950 - 1962, excluding 1951 - 1954.

$$Y_t = 18,406 + 18,403 X_1 + 7,738 X_2 + 15,812 X_3 + 23.421 I - 221.22 P_{t-1}$$

(t=7.64) (t=2.76) (t=6.49) (t=3.66) (t=2.85)

$$R^2 = 0.903$$

6.10

$$df = 30$$

Y_t = Number of lorries on farms.

I = Gross income in million rands deflated by the consumer price index. 1947/48 - 1949/50 = 100.

P_{t-1} = Price index of lorries deflated by the index of all farm labour (1947/48 - 1949/50 = 100), and lagged one year.

X_1 = 1 if Cape, 0 otherwise;

X_2 = 1 if Natal, 0 otherwise;

X_3 = 1 if Transvaal, 0 otherwise; if $X_1 = X_2 = X_3 = 0$, then Free State.

The price elasticity of farm trucks with respect to the wage rate is estimated at -1.83 which is more elastic than the price of trucks deflated by the crop price variable. The national model was constructed for the period from 1922 to 1964 and the regional model for 1950 to 1962. The difference in elasticities could be because the price variable became more elastic during the latter part of the period. An income elasticity of +.71 was estimated for the regional function.

6.6. Demand functions for pumping equipment

6.6.1. Aggregate model

The model 6.11 represents a demand function for pumping equipment used on farms covering the years 1954 - 1968. All the variables were transformed to logarithms except the time variable which is in original units.

$$Y = + 13.8810 - 0.7256 P_{Ct} - 0.01135 T - 0.3346 P_{It-1} \quad 6.11$$

(t=1.53) (t=1.00) (t=.48)

$$R^2 = .774$$

$$d = 1.91$$

$$df = 11$$

Y = Value of new pumping equipment (in thousand rands) at 1947/48 - 1949/50 prices.

P_{Ct} = Price of pumping equipment deflated by the price of crops for the current year. (1947/48 - 1949/50 = 100).

T = Time measured as the last two digits of the current year.

P_{It-1} = Price of pumping equipment deflated by the price of inputs and lagged one year. (1947/48 - 1949/50 = 100).

The price elasticity of demand according to current prices is approximately -.7. The price elasticity based on lagged prices and deflated by the price of inputs has the right sign but it is not significant.

Other variables, like cash income, were also tested in a demand model for pumping equipment but they were deleted because of signs contrary to economic theory. The reason for these unexpected signs was multicollinearity and insufficient degrees of freedom.

The only partially successful attempt was to re-run the

original model on untransformed variables, dropping P_{It-1} and in this case the price elasticity of demand for pumping equipment is $-.8$.

$$Y = 12,370 - 44,216 P_{Ct} - 59,297 T \quad 6.12$$

(t=1.78) (t=1.12)

$$R^2 = .810$$

$$d = 1.68$$

$$df = 12$$

6.6.2. Provincial model

A provincial demand model was fitted on expenditure data for the period 1954 - 1963 in the original form.

$$Y = 3,546 + 1,770 X_1 - 443 X_2 + 800 X_3 - 322 R - 8.00 P \quad 6.13$$

(t=11.09) (t=2.46) (t=5.73) (t=1.17) (t=1.10)

$$R^2 = .902$$

$$df = 34$$

Y_t = Provincial expenditure on pumping equipment deflated by its price. Price index 1947/48 - 1949/50.

R = First mortgage bond interest rate.

P = Price of pumping equipment deflated by the price of crops.

$$1947/48 - 1949/50 = 100.$$

X_1 = 1 if Cape, 0 otherwise;

X_2 = 1 if Natal, 0 otherwise;

X_3 = 1 if Transvaal, 0 otherwise; if $X_1 = X_2 = X_3 = 0$, then Free State.

The rate of interest and the real input price have expected signs but their t values are just greater than one. The estimated elasticities are respectively -1.61 and $-.55$. As in the case of new machinery and equipment the interest rate elasticity was estimated to

be higher than the price elasticity of inputs.

It seems that other factors like natural conditions which were not accounted for must also affect the demand. When farmers consider buying pumping equipment they may expect that the internal rate of return on this equipment from irrigation will cover the interest rate by far, in which case the latter will not influence the purchase.

The significance of the dummy variables can be considered as responsible for the high R^2 and not that the economic variables effectively explain the demand.

6.7. Demand functions for spare parts

6.7.1. Aggregate model

A demand equation was fitted on original data covering the years from 1950 to 1967, excluding 1951, because data were not available for that year.

$$Y_t = 19,219 + .05882 I_t - 214.64 P_t$$

(t=3.31) (t=1.73) 6.14

$$R^2 = .591$$

$$d = .45$$

$$df = 14$$

Y_t = Value of spares at constant prices. (1947/48 - 1949/50 = 100).

Spares include shares, plough discs, landsides, mouldboards, harrow teeth, harrow discs, mower knives and tractor spares.

I_t = Cash farm income in thousand rands deflated by prices of farm inputs and lagged one year. (Price index 1947/48 - 1949/50 = 100).

P_t = Prices of spares deflated by prices of inputs and lagged one year. (1947/48 - 1949/50 = 100).

The cash income of farmers and the prices of spares alone explain 59% of farmers' motivations to buy spares. Many other factors for which data are not available, like the average age of machines on farms and the introduction of new machines may be the reason for the relatively large unexplained portion.

The autocorrelation in the model is very serious according to the Durbin-Watson test. The estimators of the true parameters are still unbiased but the sampling variances may be considerably underestimated. The simple correlation coefficient between errors in period t , U_t and U_{t-1} was found to be $r = .7328$.*

The correlation coefficient r was used to transform the variables $(Y_t - r Y_{(t-1)})$, $(I_t - r I_{(t-1)})$ and $(P_t - r P_{(t-1)})$ and the simple least squares was again applied.

$$Y_t^! = 4,507 - 71.03 P_t^! + .02788 I_t^! \quad 6.15$$

(t=1.05) (t=3.32)

$$R^2 = .410$$

$$d = 1.48$$

$$df = 13$$

$Y_t^!$, $P_t^!$ and $I_t^!$ are the transformed variables. The Durbin-Watson statistic in the transformed model is greater than the upper boundary for d and the hypothesis of independence cannot be rejected at the 5% level. The signs of the variables are as expected and the coefficients of both prices and incomes are greater than their standard errors.

The quantity 4,507 is an estimate of $(1 - r)$ constant term,

* It was assumed that the autoregressive scheme is of first order where r is estimated as $\hat{U}_t = r\hat{U}_{t-1} + e_t$; $E(e_t) = 0$.

so that relation 6.15 may be stated in terms of the original values as

$$Y_t = 16,868 - 71.03 P_t + .02788 I_t \quad 6.16$$

6.7.2. Provincial model

The regional demand model estimated in original form covers the period from 1950 to 1963, excluding 1951, 1952 and 1955, because this item was not reported for those census years.

$$Y_t = 11,741 + 5,742 X_1 + 2,346 X_2 + 5,102 X_3 + 5.108 I_t - 145.6 P_t$$

(t=8.35) (t=3.57) (t=8.52) (t=2.00) (t=6.84)

6.17

$$R^2 = .886$$

$$df = 37$$

Y_t = Provincial expenditure in thousand rands on maintenance and repair of machinery deflated by its price index. (Price index 1947/48 - 1949/50 = 100).

I_t = Gross income in million rands from the main crops on a provincial basis deflated by the consumer price index. Price index 1947/48 - 1949/50 = 100).

P_t = Price of spare parts deflated by a weighted wage of White, Bantu and Coloured regular labour on a provincial basis. (1947 and 1950 = 100).

X_1 = 1 if Cape, 0 otherwise;

X_2 = 1 if Natal, 0 otherwise;

X_3 = 1 if Transvaal, 0 otherwise; if $X_1 = X_2 = X_3 = 0$, then Free State.

The significance of the dummy variables shows that there is a difference in the level of "regional" demand which has been adequately accounted for.

The coefficient of the regional income variable is twice that

of its standard error. The income elasticity is $+0.35$ which is fairly low. Farmers may prefer, with a substantial increase in income, to buy new equipment.

The price elasticity is -1.86 which indicates that farmers respond more readily to a change in relative price. This variable is highly significant. With an increase in cost of labour, farmers will substitute labour by spending more on machinery.

CHAPTER 7.

THE DERIVATION OF A PRODUCT SUPPLY ELASTICITY FROM
FACTOR DEMAND ELASTICITIES REPORTED IN CHAPTERS
5 AND 6

If inputs respond to relative price changes, so must farm output. Thus a study of input behaviour can also provide an insight into the response of farm production.

It can be shown that the supply elasticity is a weighted average of all the elasticities of demand for individual inputs with respect to the price of the product. When the factor to product price ratio is used in the demand model the demand for an input with respect to input price is forced to be equal in magnitude, but opposite in sign, to the demand for the same input with respect to product price. If it is assumed that factors get paid the value of their marginal product, then the appropriate weights are the factor shares.

Griliches (50, pp. 318-320) showed that the aggregate supply elasticity can be derived by using a production function.

$$\text{Let } Y = f(X_1, X_2, \dots, X_n) \quad 7.1$$

$$\text{then } \frac{dY}{dP_Y} = \frac{\partial Y}{\partial X_1} \cdot \frac{dX_1}{dP_Y} \dots \frac{\partial Y}{\partial X_n} \cdot \frac{dX_n}{dP_Y} \quad 7.2$$

where Y = product, P_Y = product price and X_1 = input 1.

Multiply through by $\frac{P_Y}{Y}$, then

$$\begin{aligned} \text{Elasticity of supply} &= \frac{dY}{dP_Y} \cdot \frac{P_Y}{Y} = \frac{\partial Y}{\partial X_1} \frac{X_1}{Y} \cdot \frac{dX_1}{dP_Y} \frac{P_Y}{X_1} \dots \frac{\partial Y}{\partial X_n} \frac{X_n}{Y} \cdot \frac{dX_n}{dP_Y} \frac{P_Y}{X_n} \\ &= \sum_1 a_1 E_1 \end{aligned} \quad 7.3.$$

where a_1 = elasticity of output with respect to change in factor 1.

When a perfect market* is assumed then a_i will be equal to that factor's distributive share (b_i), and E_i = elasticity of demand for factor i with respect to the price of the product.

$$\text{Then elasticity of supply} = \sum_i b_i E_i \quad 7.4$$

The model also rests on the assumption that factor prices are fixed** and that the supply of factors is infinitely elastic.

Factor demand elasticities were not estimated for all the resources because of inadequate data. Elasticities of fertilizers and feed were assumed to be representative of the whole current inputs category. Elasticities in respect of tractors, trucks, pumping equipment and other machinery and implements cover the whole machinery category. The elasticity of demand of land was assumed to be zero because of the fixed supply.*** The demand elasticities of improvements and livestock were not estimated by the least square's fitting of a demand model.**** Based on studies of Foote (39) and Muth (105) the long run elasticity was taken as unity.

The various elasticities were weighted by the distributive shares of the categories which they represent. For example, fertilizers and feed were weighted by the share of the current inputs category and in accordance with their relative importance in this category. The average factor shares for the five year period

* $\frac{\delta Y}{\delta X_i} = \frac{P_{X_i}}{P_Y}$ There is, however, no reason to assume that resources are paid the value of their marginal product.

** Several researchers, however, reported a correlation between factor price and product price.

*** The derived demand elasticity of land (Section 4.1.5.2) was found to differ from zero. The two ways of deriving a supply elasticity are treated as completely independent.

**** These elasticities were derived from the production function in Section 4.1.5.2.

1961/62 - 1965/66 were used as weights for the demand elasticities.

TABLE 7.1. THE DERIVATION OF THE AGGREGATE PRODUCT SUPPLY ELASTICITY FROM ELASTICITIES OF DEMAND FOR RESOURCES WITH RESPECT TO PRODUCT PRICE. SOUTH AFRICA.

Resource	Resource demand elasticity with respect to product price	Weights based on factor shares	Weights based on production elasticities
Labour	0.5	.192	.230
Trucks	1.0	.057	.051
Tractors	1.0	.045	.041
Pumping equipment	0.7	.013	.011
Machinery and implements	1.2	.026	.023
Fertilizers	1.0	.162	.116
Feed	0.9	.117	.136
Land	0.0	.180	.080
Improvements and livestock	1.0	.208	.341
Weighted elasticity of supply		0.7	0.8

When a lag model is not used the estimated elasticity can be taken as a long or a short run elasticity because adjustment is assumed to be instantaneous. Bearing this in mind then, the estimated elasticity of supply can be considered as somewhere between a short run and long run elasticity.* This elasticity weighted by factor shares was estimated as 0.7 in Table 7.1. Factor demand elasticities were also

* The writer arrived at this conclusion from his own observations and also by studying results of other researchers. The short and long run elasticities of demand of the lag model are usually respectively smaller and larger than the elasticity computed, when the lag model is not assumed.

weighted on the basis of production elasticities. The production elasticities were derived for the agricultural industry and presented in model 4.21 of Chapter 4. The weights of items included in all farm machinery were derived using the production elasticity of all farm machinery and the relative importance of each item in this category. The weights for fertilizer and feeds take into account the relative production elasticities of these resources, as well as the relative importance of the current inputs category. All the weights sum up to 1.029 which is the returns to scale of model 4.21. Using production elasticities as weights, the elasticity of supply was estimated as 0.8. Griliches (50, p. 320) estimated the short and long run elasticities of supply for the U.S.A. respectively as .28 and 1.20, the average of which is very close to the elasticities calculated in Table 7.1.

While the elasticity of supply derived in this way is severely limited by the assumptions, it still indicates that the supply of agricultural products may not be completely inelastic.

CHAPTER 8.

DISCUSSION AND CONCLUSIONS

The most serious problem encountered was, that for certain resources, time series data were only available from the 1950's. This factor limited the degrees of freedom in the regression models to a considerable extent. However, Minden (101) who investigated the demand for new farm machinery, found it necessary to use different models for each of the periods 1911 - 1962 and 1946 - 1962 for the U.S.A. The latter period was studied after he found that a significant shift in farm machinery demand had occurred after World War II. A synthesis of some of the more important conclusions will now be given.

This thesis consists of separate parts in the sense that in each part a different aspect of the problem was studied. All the sections however, had the common aim of investigating the resource structure of the Agricultural Industry in South Africa. To eliminate confusion, the results of each section will be separately presented and wherever necessary, contrasted.

1. Aggregate and regional production functions

A production function for the Agricultural Industry in South Africa was constructed by using data of the 1959/60 comprehensive agricultural census. The following variables were incorporated in the model: current expenditure, labour, machinery, tools and implements, land, livestock and percentage of farm income from livestock. A strong complementary relationship was encountered between current expenditure and machinery, tools and implements and the two inputs were consequently pooled. From this production function the following main conclusions can be derived:

(1) All the production factors cited, except land, were significant in explaining total production. In the model where land input had a significant coefficient, the sign was negative.

(2) The percentage of income from livestock variable was introduced to take into account differences in farming organisations. This variable was not only significant but it forced the elasticity of land in the expected direction and made the livestock input more significant. By including this variable, the coefficient of the land variable experienced a marginal change towards the positive side.

(3) Ten dummy variables were introduced to consider structural differences in production amongst the eleven agro-economic regions. These variables accounted for productivity differences between regions and only two out of the ten had standard errors greater than their regression coefficients.

(4) By fitting a production function in the usual way, the research assumes that each firm or region shows the same response in production for a given input change. This rigid assumption was relaxed somewhat by making the coefficients dependent on the output mix for each of the regions. The same resources turned out to have completely different elasticities for farms with different output mixes. For example, current inputs had an elasticity of .10 on a 100% livestock farm and an elasticity of .73 on a 100% crop farm. Livestock input had an elasticity of .62 on a 100% livestock farm and an elasticity of .10 on a 100% crop producing farm.

(5) Returns to scale for the different models were between .90 and .97, indicating diminishing returns to scale. It was greater for a crop producing farm than for a livestock farm, implying that

the economies of scale are mostly found on a crop producing farm. Thus aggregate production cannot be increased when farms are consolidated into larger ones.

The resource data for the Agricultural Industry were also analysed using the technique of principal components. The object of component analysis is to economize in the number of variates. These variates were transformed into new orthogonal variates which accounted for as much of the variation in the resource data as possible. It was shown that the effective dimension of the six production factors previously cited, could be reduced to three or four variables. An interesting result emerged from the linear transformations, namely that the crop associated inputs; current expenditure, labour, machinery, tools and implements and land tended to group together in the first and fourth component, while the livestock inputs tended to group together in the second and third components. The land input appeared in all the components probably because land is a common input to both enterprises. On the basis of the new components, a production function was estimated which explained 87% of the variation in production. In the production function the land input again turned negative. It appeared as if reasonable estimates were obtained from this model for current expenditures and machinery, tools and implements. Using multiple regression, earlier it was not possible to estimate the separate effects of these inputs.

Estimating the partial contribution of all factors simultaneously as in multiple regression, has the serious disadvantage that only a limited number of inputs can be considered because of multicollinearity. The factor share approach eliminates this tedious

problem and it has no limit on the number of factors that may be considered. The following inputs for the period 1949/50 - 1965/66 were considered for the industry: fertilizer, labour, all farm machinery, land, livestock, fuel and repair charges of all farm machinery, farm feeds, dips and sprays, fixed improvements and other operating inputs. In the estimation of the share of a factor, which is also the elasticity, an adjustment to equilibrium was assumed. The equilibrium factor shares for the nine inputs were estimated by ordinary and autoregressive least squares using the F test as the main decision criterion. Adding the nine elasticities, the returns to scale was estimated at 1.02.

Bearing in mind the pros and cons of the factor share approach and the production function method, where all resources are estimated simultaneously, a production function model was built incorporating results obtained from both procedures. The following main conclusions were derived from this technical relationship:

(a) The elasticities of substitution between any two inputs were shown. From a policy point of view these relationships may be considered as extremely important. A 1% increase (decrease) in labour was estimated to result in a 1.81% decrease (increase) in machinery given that production is unaltered and a 1% increase (decrease) in fertilizer will result in .78% decrease (increase) in land. Estimates can thus be made of the quantities of other resources required to substitute for the outmigration of farm labour.

(b) Assuming the product market to be in equilibrium, the factor demand elasticities for the nine inputs were computed. The factor demand elasticities were shown to be very sensitive to changes in the assumed product demand elasticity. The factor demand

elasticities indicate the expected change in resource use as a reaction to a given change in factor or product prices.

(a) Simple supply elasticities were derived for the inputs, when certain necessary restrictions on the economic system were imposed. From this information, short run, intermediate run and long run supply elasticities for the Agricultural Industry were computed. The results disprove some of the conventional ideas that the supply of agricultural products in South Africa tend to be completely inelastic, even in the long run.

(d) The constant term of the production function was computed and with this function, completely specified, marginal products of resources were derived. The marginal product of land turned out to be very low, while the marginal products of livestock, farm feeds, dips and sprays, and labour are very high. The results show that land is abundant and production can be increased through the intensification of production on a smaller area. This is a most important conclusion, which has been confirmed in various micro-production studies of groups of farmers who keep farm accounts.

(e) Keeping production at the average level of the period, the allocation of resources to ensure minimum cost is shown. Permitting all resources to vary, costs can be reduced from R411.3 m to R357.3 m, with production unchanged. When resource use was restricted to more realistic bounds, it was still able to reduce costs by 6.4%.

(f) The optimum allocation of resources was computed to ensure maximum profits. To keep allocation within realistic bounds certain restrictions were imposed on some of the inputs. Comparing the optimum plan with the actual allocation it was seen that costs increased by R8.6 m, but output by R38.8 m. Profits as a

consequence increased from R115.7 m to R146.2 m or by 26.4%. In the optimum plan more intensive use of the following resources was made: fertilizer, all farm machinery, livestock, farm feeds, dips and sprays, fixed improvements and other operating inputs. It can be concluded that land was used inefficiently and was considered to be in 'oversupply'.

With the information on output and inputs contained in the 1959/60 agricultural census, production functions for ten agro-economic regions were estimated. It appears that almost constant returns to scale prevailed for all regions. The marginal products per R100 of input of labour, machinery, tools and implements, and livestock were considerably in excess of 100 in respect of regions for which estimates were made. Marginal product estimates for labour and livestock were made for all regions but only for the A, B and K regions for machinery, tools and implements. The marginal product of land was greater than 100 for the B and K regions, for the other eight regions it was either less than 100 or negative. Machinery, tools and implements, and current expenditure combined had marginal products in excess of 100 for seven regions. For most regions R^2 were recorded between .80 and .95, indicating that a satisfactory portion of the variation in per farm production could be explained.

2. Time series demand functions for operating inputs and labour

The amounts of resources such as fertilizers and machinery that farmers buy annually are determined by factors like the price of the resource, the product price, prices of other resources, and income. Results obtained from models of this type will now be discussed.

From 1952/53 until 1965/66 consumption of fertilizer plant nutrients in South Africa increased approximately $3\frac{1}{2}$ times while the absolute price of plant nutrients decreased by almost 20%. It was assumed that farmers are more interested in the weight of plant nutrients than in the total weight of the fertilizer. The following factors were found to have an important effect on the amount of fertilizer purchased: price of fertilizer, cash income of farmers, price of land, capital assets and the price of crops. The following variables in a current and lagged form explained consumption: land prices, capital assets and fertilizer price. The direct and cross price elasticities of the explanatory variables were approximately as follows: income .8, land price (lagged) +1.2 and capital assets +1.6. Assuming instantaneous adjustment, the fertilizer price elasticity was estimated at -1.0. Allowing for a lag in response to price changes, the short run elasticity of the fertilizer price was estimated at -0.75 and the long run elasticity at -2.50. It was also estimated that approximately 80% of the indicated adjustment should be completed within five years. A strong complementary relationship existed between purchases of fertilizer and capital assets. Tractor numbers, when used in a model, also showed a very strong complementary relationship. It seems reasonable that the introduction of the tractor into the farming enterprise must have had a tremendous stimulating effect on the application of fertilizer. Capital assets as such are an indication of the purchasing power of a farmer and can be expected to have a positive influence on demand. A relationship of substitution was found between land and fertilizer. If all fertilizer suppliers reduce the price of fertilizer, then it is expected that their total revenue will decrease in

the short run but increase in the long run. Whether profits of fertilizer suppliers would increase in the long run with a reduction of the fertilizer price, depends on the cost conditions of supplying the greater quantity. A 1% subsidy on fertilizer price is expected to increase consumption by about .75% in the short run and 2.5% in the long run.

Weights derived from a regression of nutrient content of N, P and K on the value of the mix, were also used to aggregate tons of these nutrients. A model with the weighted consumption of fertilizer had very satisfactory results.

In order to increase the degrees of freedom, dummy variables were used to incorporate provincial data on fertilizer into one model. This step was rewarding and was used for most of the other resources.

The following variables, seemed to have a significant effect on feed purchases: price of feed, income, price of dairy products, and time. Both price and income elasticities, on a current and lagged basis, appeared to be less than one. Because of the importance of maize feed in South Africa, its demand was estimated separately. Not allowing for a lag, the elasticity of the price of maize deflated by the price of dairy products was estimated at approximately -1.65. Using a distributed lag model the short run elasticity of maize was estimated at -.77 and the long run at -8.2. It appears as if the long run estimate is too high. The result of an elastic long run demand is encouraging and shows that by reducing maize feed prices, feed consumption and total income could be increased considerably.

The demand for fuel and lubricants may be seen as both derived from the machinery stock and as a direct function of the price of fuel

and lubricants and other variables. In a direct function the price of fuel and lubricants, the price of land and income were found to have an influence on the use of this resource.

The following variables were significant in explaining labour numbers on farms: wages, capital assets, prices of all farming requisites, prices of products, prices of machinery, and prices of operating inputs and machinery. Each of the deflators had a different effect on the wage elasticity. The average wage elasticity was approximately $-.60$. Using a distributed lag model and deflating wages by prices of products, a short run elasticity of $-.44$ and a long run elasticity of $-.63$ were arrived at. Because labour prices were deflated by product prices, a 1% increase (decrease) in product price was estimated to increase (decrease) the demand for farm labour by .44% in the short and .63% in the long run. The capital assets variable indicated a complementary relationship between assets and labour numbers. Based on data for the provinces of Natal, Transvaal and Free State, a model with dummy variables was constructed for Bantu regular labour. An increase of 1% in Bantu wages was estimated to release .51% of Bantus for the non-agricultural sector. In terms of actual figures an increase in Bantu wages of R0.72 should release approximately 3,400 regular Bantu employees. A very strong complementary relationship was found between numbers of tractors and Bantu labourers. In South Africa the Bantu wage rate in relation to prices of other resources, decreased slightly from 1946 to 1963 with the result that farmers have not found it economically profitable to substitute capital items for labour as is the case in the U.S.A. It may be more appropriate to estimate labour demand by simultaneous equations because of the bilateral causation of labour numbers and wages.

3. Time series demand functions for farm machinery, and a derived supply elasticity

The demand for farm machinery is a demand for a durable item and as such is an investment decision. It may also be argued that it is a demand for a stock, not a flow because it is the total stock of machines that enters the production function as an input. Models for different durable inputs will now be discussed.

Real cash income, prices of spare parts, of other inputs and the labour wage rate had a significant effect on purchases of spare parts. The Durbin-Watson statistic improved after a lagging procedure was applied to reduce autocorrelation. The income elasticity for spare parts was low (.35), probably because farmers prefer to buy new equipment when there is a substantial increase in income. The price elasticity of -1.86 could be an indication that farmers respond more readily to a factor price change than to an income change.

The price of all machinery and the parity ratio were the more important variables in explaining the demand for new machinery, implements and tractors. An increase in the parity ratio will improve the relative position of the farmer, make him more optimistic and consequently stimulate investment.

The following variables explained the major part of the demand for new machinery and implements: price of machinery, price of crops, interest rate of first mortgage bonds and time trend. A drop of 1% in the interest rate was estimated to stimulate investment by 1.38%. According to the theory of the firm, the demand for a durable item is also a function of the interest rate. Minden (101) when estimating the demand for new farm machinery experimented with different interest rates as decision variables while Griliches (53) used the first

mortgage bond interest rate to estimate the demand for tractors. Both approaches are considered to be in order. What is important is that the interest should be of a medium term nature because investment in machinery is of a medium term. The time variable could be significant because important variables are omitted or because it is an indication of the improvement of technological knowledge.

In a stock demand model with the number of tractors as a dependent variable, the following factors were found to be of importance: price of tractors, farm wages, real income, price of land and the livestock crop price ratio. A model consisting only of the price of tractors and lagged tractor numbers explained 99.8% of the variation in tractor numbers. The short and long run demand were shown to be relatively inelastic (-0.38) and elastic (-1.43) respectively. When instantaneous price adjustment was assumed, the elasticity was -0.96. The cross price elasticity of tractor numbers and the price of land was positive, suggesting that the two inputs substitute for one another. To some extent these two resources may be either seen as substitutes or complements. The livestock price/crop price variable was positive, which could mean that the livestock price variable was the more important decision variable. The income variable had the expected sign, but was marginally smaller in absolute terms than the tractor price elasticity.

In explaining the demand for pumping equipment, the following variables had t values greater than 1.0: prices of pumping equipment deflated by crop prices, time and the first mortgage bond interest rate.

The following variables explained the demand for farm trucks satisfactorily: the truck/crop price ratio, the truck/labour price

ratio and gross income in real terms. The distributed lag model suggested a short and long run truck price elasticity of $-.34$ and -1.0 and a short and long run income elasticity of $+.79$ and $+2.32$ respectively. The adjustment coefficient showed that 34% of the adjustment to equilibrium was completed within the first year. Because of the large money outlays involved in the purchases of trucks and tractors the difference between the short and long run demand can be expected.

The supply elasticity of total production can be written as the weighted sum of all the factor price elasticities of demand with respect to the price of the product. Resting on the assumption that all factors get paid the value of their marginal product, the factor demand elasticities derived from the time series demand models were all weighted by their respective factor shares. Because factor demand elasticities were not computed for all resources, elasticities derived were assumed to be representative of the groups under which they are classified. The product elasticity of supply was estimated respectively at 0.70 and 0.80 when factor shares and production elasticities were used as weights, which suggests that the supply of agricultural products is responsive to product price changes and not completely inelastic.

CHAPTER 9.

SUMMARY

In this study, factor demand elasticities were estimated from time series demand functions and derived from macro production functions. Direct demand and cross price elasticities for the following inputs were derived from a production function for the South African agricultural industry: fertilizer, labour, all farm machinery, land, livestock, fuel and repair charges of all farm machinery, farm feeds, dips and sprays, fixed improvements, and other operating inputs. Factor demand elasticities using time series data were estimated for fertilizers, farm feeds, fuel and lubricants, farm labour, spare parts of farm machinery, new machinery including implements and trucks, tractors, pumping equipment and farm trucks.

Product supply elasticities were derived from factor demand elasticities and macro production functions. When input demand elasticities were weighted according to production elasticities and factor shares respectively, estimates of product supply elasticities of 0.8 and 0.7 were obtained. A supply elasticity of .34 in the short run and 2.56 in the intermediate run was derived from macro production data. The hypothesis of a perfectly inelastic commodity supply function is thus rejected on the basis of available data. Therefore, the Industry will increase production if given the economic incentive of favourable prices.

In the past two decades agricultural output in South Africa increased for some commodities in the face of falling real product prices from which some people may have gained the impression that the product supply curve is backward bending. The producer's price of

maize relative to the price of all farm requisites dropped for example, by 15% in the last decade, while the production of maize on farms of Whites almost doubled. The answer of course, is that the adoption of new technological techniques such as hybrid maize shifted the supply curve far to the right resulting in a lower price and increased output. Positive supply elasticities were also obtained by Griliches (50) and Tweeten and Quance (135) for the U.S. Agricultural Industry.

On the basis of the production function, it does appear as if resources are not used in the most efficient way and it was shown that profits could be increased by 26.4% when resources are reallocated. Optimum production was arrived at through equating the marginal cost of every resource to the marginal revenue resulting from that resource and solved within the framework of the production function. It was also shown that the same output can be produced with fewer resources. Restricting resources to realistic bounds, it was still possible to reduce costs by 6.4%.

Production functions were estimated from cross sectional data from the different magisterial districts as reported in the 1959/60 agricultural census. However, serious multicollinearity was encountered. For example in the first production function model, the current input variable turned out to be negative due to a correlation of this variable with the machinery input. These variables were consequently pooled by way of simple addition. Production elasticities for nine inputs were also estimated by the factor share approach which, while not limited by intercorrelations, gave highly satisfactory results.

The production elasticities were estimated as follows:
fertilizers .062, labour .230, all farm machinery .127, land .080,

livestock .230, fuel and repair charges of farm machinery .063, farm feeds, dips and sprays .073, fixed improvements .111, and other operating inputs .053. On inspection the production elasticity of livestock does appear to be overestimated and the elasticity of land to be underestimated. This will be the case if the quality of land is better reflected in the livestock variable than in the land variable. The value of land was used as the land variable but it is subject to a fair amount of measurement error as it is based on subjective estimates of farmers. It also is reasonable to assume that the stocking rate is a fairly good index of the quality of land.

In most factor demand models, the price of the factor in question, the prices of substitute or complementary factors, the price of the product and income were shown to be important in decision-making. The price of the factor in question does appear to be the most important decision variable. Prices of variable factors were included in the demand models, but quantities of fixed factors. The demand for machinery items was treated separately from that of operating inputs as the demand for the former was considered as an investment demand. In order to increase the degrees of freedom for the models, provincial data were used by introducing dummy variables. The statistical tests for these models showed an improvement on that of the national models. The high R^2 for these models is misleading and partly due to a difference in the level of resource use in the various provinces. The Durbin-Watson statistic for serial correlation is reported for all time series equations, but not for combined time series and cross sectional models.

The factor demand elasticities of time series models were shown to differ for the various resources. These elasticities were

generally lower for operating inputs (except long run elasticities of fertilizer and maize feed) and labour ($\epsilon < 1$) than for farm machinery items ($1 < \epsilon < 2$). The rate of interest was found to have a marginal effect on investment behaviour in the case of new machinery and implements and pumping equipment.

Where short and long run elasticities were estimated for inputs, they differed distinctly. The short and long run price elasticities are estimated for fertilizer as $-.75$ and -2.50 and for maize feed as $-.77$ and -8.2 respectively; for tractors, for example, these were estimated at $-.38$ and -1.43 respectively. The short run price and income elasticities for farm trucks were estimated at $-.34$ and $.79$ and the long run price and income elasticities at -1.00 and 2.32 respectively. In the long run an overall reduction of prices of these machinery items may not be expected to lead to a reduction of total income for machinery suppliers. The price elasticities for specific brands of farm machinery, say Case tractors, can be expected to be considerably higher than that for the aggregate input of all branches. The same applies to the brands of other farm inputs. It may reasonably be said that price reductions for specific brands of farm machinery, if not matched by reductions of other competitive brands, could lead to an increase of total income to those suppliers. A reduction of the fertilizer price for a specific brand of fertilizer can be expected to increase the income of the company concerned.

The demand for fertilizer for the industry being elastic and keeping in mind that the demand for the brand of a specific company is even more elastic than that of the industry, it does appear as if a firm could increase its profits by reducing its price. Because of the oligopolistic nature of industrial firms supplying farm inputs, any reduction of input prices by a specific firm can be expected to be

followed by similar reductions in prices of other firms.

In the light of these results it is interesting to follow the price war that is at present (May-June, 1970) being waged between the main fertilizer companies in South Africa.

With an elastic demand for maize feed, total income and the amount of maize feed consumed should increase with a decrease of the maize price or increase in livestock prices.

From the models it does appear that land and the inputs that have been estimated substitute for one another, while the same inputs that substitute for land are complement of capital assets.

Factor demand elasticities derived from the aggregate production function, were directly dependent on an assumed product demand elasticity. For example, for the following assumed product demand elasticities, $-.25$, $-.75$, - the factor demand elasticities of fertilizer varied respectively: $-.84$, $-.98$ and -1.07 . In general, the more elastic the product demand, the more elastic the factor demand.

The purpose of this dissertation is not to formulate agricultural policy but some of the estimated parameters may cast some light on the possible effects of different policies. With a knowledge of the demand elasticities of the various resources, estimates can be made of the effectiveness of subsidization programmes. Knowing the appropriate magnitudes of the production function parameters, estimates can be made of the effect on total production as a result of resource changes. For example, with a relatively elastic demand for fertilizer, the present subsidies on this input must stimulate consumption considerably. Suppliers of certain inputs could also be convinced not to increase their prices where the demand for these factors is elastic, because of the negative effect of such policies

on their incomes.

The study shows that the factor/product price ratio is an important decision variable in determining the amounts of various inputs purchased. These demand relationships may serve as bases to evaluate different programmes in order to attain policy targets such as either lower or higher production. The desirability of such targets or otherwise is beyond the scope of the thesis.

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APPENDIX

A. SOME OF THE STATISTICAL LIMITATIONS

No attempt will be made to give a detailed and rigorous treatment of this problem because these topics are discussed in almost any book on econometrics.* It was, however, considered appropriate to highlight some of the implications if the assumptions of the linear model are not satisfied.

(a) Multicollinearity

The presence of multicollinearity was found to be the most serious limitation in the time series and cross-sectional analysis reported in this study.

Multicollinearity arises when some or all of the explanatory variables are so highly correlated that it becomes difficult to obtain good estimates of the relative effects of these variables (83, p. 201).

These high intercorrelations increase the standard errors of the net regression coefficients and make the latter unstable. Johnston (83, p. 205) illustrates with a numerical example that increasing intercorrelations of the explanatory variables does not necessarily increase the coefficient of determination.

Wallace (144) developed a fruitful expression for multicollinearity by using the mean square error criterion.

Suppose the true model is

$$Y = b_{y1.2} X_1 + b_{y2.1} X_2 + U_t \quad 1.$$

$$U_t \sim N[0, \sigma^2].$$

* For a rigorous or more complete exposition see:

- (1) Goldberg, A.S. *Econometric Theory*. 1965. John Wiley & Sons,
 - (2) Johnston, J. *Econometric Methods*. 1963. McGraw-Hill Book^{Inc.}
 - (3) Malinvaud, E. *Statistical Methods of Econometrics*. Company.
- North Holland Publishing Company, Amsterdam. 1966.

The variances of b_1 and b_2 are

$$V(\hat{b}_{y1.2}) = \frac{\sigma^2}{\sum X_1^2 [1 - r_{12}^2]} \text{ and } V(\hat{b}_{y2.1}) = \frac{\sigma^2}{\sum X_2^2 [1 - r_{12}^2]} \quad 2.$$

The variances of \hat{b}_1 and \hat{b}_2 will 'blow up' as the simple correlation r_{12} approaches unity.

If X_2 is dropped from the model then the variance of $\hat{b}_{y1.2}$ will decrease but some bias is introduced into the new model. The regression coefficient of X_1 after dropping X_2 is \hat{b}_{y1} .

Then it can be shown that

$$\frac{b_{y2.1}^2}{\text{Var}(\hat{b}_{y2.1})} < 1 \text{ as } \text{MSE}(\hat{b}_{y1}) > \text{MSE}(\hat{b}_{y1.2}) \quad 3.$$

where

$$\text{MSE}(\hat{b}_{y1}) = \text{Var}(\hat{b}_{y1}) + (\text{Bias } \hat{b}_{y1})^2$$

$$\text{MSE}(\hat{b}_{y1.2}) = \text{Var}(\hat{b}_{y1.2})$$

Based on this criterion, Wallace (131) developed a useful test to detect multicollinearity using the non-central F-distribution with a noncentrality parameter equal to one-half. With one degree of freedom in the numerator the ordinary $(t \text{ value})^2$ computed can be compared with the critical points for the mean square error test as tabulated by the same writer. With this mean square error test, a bigger calculated statistic (t or F value) is required, assuming the same level of significance. When no a priori information on the variable in question is assumed, a significance level of $\alpha = .50$ can be used and variables with t values marginally greater than one are included.

Haitovsky (63) shows that the maximization of \bar{R}^2 (corrected multiple correlation coefficient) is achieved by retaining all regression coefficients whose associated t - statistics are larger than unity and

discarding all which are not.

The correct multiple correlation coefficient can be calculated from R^2 as follows:

$$(1 - \bar{R}_p^2) = \left(\frac{n-1}{n-p-1} \right) (1 - R_p^2) \quad \begin{array}{l} \text{where } n = \text{number of observations} \\ p = \text{number of independent variables} \end{array}$$

This implies that $\bar{R}_p^2 > \bar{R}_{p-1}^2$

if and only if $t > 1$.

The usual procedure to detect multicollinearity is to examine the simple correlations. If the simple correlation is greater than .9 it is better to either acquire new data, combine some of the data series or to use both cross-sectional and time series data. Cross-sectional data are however, more long run in nature while time series data reflect short run fluctuations (92).

Malinvaud (96, pp. 187-192) shows with numerical examples that the introduction of a variable highly correlated with others in the model makes the coefficients concerned highly uncertain without having any perceptible change in the predictions. Standard errors of variables not highly correlated with the new variables changed very little.

(b) Autocorrelation

Autocorrelation arises when there is serial dependence in the error term.

The main sources of autocorrelation are: incorrect specification of the form of the relationship between variables, omission of relevant variables, and errors of measurement (83, pp. 177, 178).

The Hildreth and Lu procedure, von Neuman ratio and the Durbin and Watson test can be used to test for autocorrelation. The Durbin-Watson test was used in this study. This statistic has, however,

several shortcomings.

- (a) It is only applicable for fixed exogenous variables. When lagged dependent variables are used the explanatory variables are not fixed any more. Most researchers report the Durbin-Watson statistic in lag models. Nerlove and Wallis say that the widespread use of this statistic stems from a misinterpretation of Durbin's papers (108, pp. 235-238). When lagged endogenous values are included, the Durbin-Watson statistic is asymptotically biased towards 2.
- (b) The indeterminant range for the statistic is large when the degrees of freedom and the number of independent variables are small.

Johnston (83, p. 177) states the main consequences of autocorrelation as follows: first, coefficients will have unbiased estimates but the sampling variances may be large; second, it is likely that a serious under estimate of the sampling variances will be obtained and third, inefficient predictions will be obtained. According to Johnston (83, pp. 215-216) the simultaneous presence of complications of lagged variables and autocorrelated residuals may lead to a substantial bias.

(c) Errors in independent variables

A condition for the least squares model is that the independent variables are fixed and measured without error. If this is not the case then the least squares estimates are likely to be biased; the standard error of estimate will increase and correlation will decrease. The bias is towards zero for large samples (83, p. 6).

In the demand models reported in this study the independent

variables were measured with more precision than the dependent variables. In most cases the dependent variable was derived as a ratio of expenditure and price. Tweeten (132, p. 52) points out that aggregation of variables* may be a potential source of error. Griliches and Grunfeld (58) derived relationships between macro and micro-estimates in terms of the micro-distribution error correlations. They concluded that if the correlations between the micro-error terms are negative, the macro-estimate will be superior to the summed micro-estimates. When specification error exists, there is also a good possibility that the macro-estimate will be superior to the summed micro-estimates.

There is no easy method to account for errors in measurement. Johnston (83, p. 166) for example suggests the use of an instrument variable. This variable is presumed to be independent of the measurement errors on the dependent and independent variables.

(d) Least squares bias

This arises when the assumption that the covariance between the error term and the independent variable must be zero, is not met. This may be the case in economic analysis when one or more variables are simultaneously determined. An example in agriculture could be labour wages and labour numbers. In lagged models the least squares coefficients remain consistent and efficient in large samples, but may be biased (132, pp. 68-73).

(e) Other sources of error and misinterpretations

Tweeten (132, p. 47) points out that the assumption that the parameters are constants and enter the model linearly cannot be met

* H. Theil discussed this problem in great detail in "Linear aggregation of Economic Relations". 1954. North Holland Publishing Co.

because of the changing structure of agriculture. Changing structural parameters may arise from droughts, depressions, inflations, wars and technological change. As a precaution a relatively short period, when the structure is relatively homogeneous, can be selected. A time variable may also be used as a proxy variable for dynamic changes like technology, improved knowledge, etc.

If heteroscedasticity is present in the errors, then the estimates remain consistent and unbiased but they are inefficient. This may be remedied by transforming the data to logarithms. The structure then becomes multiplicative rather than additive.

Griliches (53, pp. 186, 187) shows that in the lagged model the multiple correlation coefficient "must be taken with a grain of salt". Let equation 4 be a lag model with Y_t dependent, X_t independent, b the adjustment coefficient and U_t the error term, then:

$$\log Y_t = ba_0 + ba_1 \log X_1 + \dots (1 - b) \log Y_{t-1} + bU_t \quad 4.$$

This equation can also be estimated in the following form:

$$\log Y_t - \log Y_{t-1} = ba_0 + ba_1 \log X_1 + \dots -b \log Y_{t-1} + bU_t \quad 5.$$

If 4 and 5 are estimated independently, the same coefficients will be obtained (except for the coefficient of $\log Y_{t-1}$ which will be equal to $-b$) and exactly the same significance levels for the other variables. The only difference will be the multiple correlation coefficient which will usually be lower in 5 than in 4.

(f) Data limitations

In some quantity and price series, quality differences are not accounted for. Griliches (48) states that the disregard of quality differences in the labour input in production functions leads to an upward bias in the estimate of the elasticity of capital inputs,

downward bias in the estimate of the elasticity of labour inputs and to a downward bias in the estimate of returns to scale. For this reason expenditure on labour was used in this study as the input variable in order to take into account some of the quality differences in labour. In the time series demand functions, however, it was not possible to consider quality differences over time, such as education of the labour force. Quality differences in machinery and other inputs over time, as in the case of improved machines, could not be measured. This leads to an overestimate of the price index and an underestimate of the real value of the input. In demand models, prices were used as ratios. If the quality of both factors in the ratio improves over time then some of the quality improvement may be "cancelled out". The quantity series on the contrary are subjected to measurement error both of prices and of input expenditure.

B. PRODUCTS AND INPUTS USED IN PRODUCTION
FUNCTIONS REPORTED IN CHAPTER 4.

1. Products. Production is reported on a quantity basis in the census. To arrive at an aggregate production figure, the quantity of each crop was multiplied by its price. The gross production figure was coded to the nearest hundred rand. The following crops were considered for the various magisterial districts:

- | | |
|---|--|
| 1. Maize | 33. Dried fruit |
| 2. Wheat | 34. Vegetables (all Whites and urban non-Whites) |
| 3. Oats | 35. Vegetables (rural non-Whites) |
| 4. Barley | 36. Onions |
| 5. Rye | 37. Wool |
| 6. Kaffir corn (Sorghum) | 38. Mohair |
| 7. Lucerne hay | 39. Karakul pelts |
| 8. Oats hay | 40. Ostrich feathers |
| 9. Teff grass (hay) | 41. Cattle consumed in controlled and outside areas, farms of Whites and Reserves |
| 10. Other hay | 42. "Dead" cattle consumed in Reserves |
| 11. Soybeans | 43. "Dead" cattle consumed on farms of Whites |
| 12. Cowpeas | 44. Sheep consumed in controlled and outside areas, farms of Whites and Reserves |
| 13. Other edible dried beans | 45. "Dead" sheep consumed in Reserves |
| 14. Dried peas | 46. Pigs consumed in controlled and outside areas, on farms of Whites and by non-Whites in rural areas |
| 15. Sugar cane | 48. Fresh milk |
| 16. Chicory | 49. Cream sold |
| 17. Tobacco | 50. Farm butter |
| 18. Cotton | 51. Industrial milk |
| 19. Groundnuts | 52. Farm cheese |
| 20. Sunflower seed | 53. Eggs |
| 21. Wattle bark | 54. Poultry slaughtered |
| 22. Potatoes | |
| 23. Sweet potatoes | |
| 24. Citrus fruit | |
| 25. Deciduous fruit fresh consumption (all Whites and urban non-Whites) | |
| 26. Deciduous fruit fresh consumption (rural non-Whites) | |
| 27. Deciduous fruit exported | |
| 28. Deciduous fruit canned | |
| 29. Pineapples | |
| 30. Bananas | |
| 31. Other subtropical fruit | |
| 32. Viticultural products | |
| | 55. Other. |

2. Current inputs consist of:-

- | | |
|--|-----------------------------------|
| 1. Packing materials | 10. Feed purchased |
| 2. Fuel | 11. Hay for forage |
| 3. Building material for repair and maintenance | 12. Maize for forage |
| 4. Fencing material for repair and maintenance | 13. Maize for seed |
| 5. Fertilizers and soil dressings | 14. Wheat for seed |
| 6. Preventive control, curative treatment and weed eradication | 15. Oats for seed |
| 7. Maintenance and repairs of tractors | 16. Rye for seed |
| 8. Maintenance and repairs of other machinery | 17. Barley for seed |
| 9. Stock and poultry feed | 18. Cowpeas for seed |
| | 19. Groundnuts for seed |
| | 20. Sunflower seed for seed |
| | 21. Potatoes for seed |
| | 22. Dried beans and peas for seed |

23. Other farm expenditure

The aggregate input was coded in ten rand units.

3. Labour. This includes cash wages and salaries and payments in kind of Whites, Coloureds, Asiatics and Bantus. This variable was coded in units of ten rands. Total estimated money value of payments in kind include rations, such as mealies, meal, slaughter animals, meat, fish, milk, wine, bread, coffee, sugar and other goods such as tobacco, clothes, shoes, medicines, etc. The rental value of free housing is, however, not included (16).

4. Land. The estimated value is the total selling value of the holding or farming unit, including dwelling house, other buildings and fixed improvements. The interest on land was coded in units of ten rands.

5. Livestock. The numbers of sheep, cattle, pigs, goats and poultry were multiplied by their respective prices to obtain an aggregate value of livestock. The interest on the value of livestock was not coded.

6. Machinery. The depreciation of all farm machinery is reported in the 1959/60 agricultural census. This variable was coded in units of ten rands.

C. STATISTICAL SOURCES FOR TIME SERIES DEMAND MODELS

Price series were obtained from:

- (1) Supplementary data to the abstract of agricultural statistics. Division of Agricultural Marketing Research, Pretoria. January, 1969.
- (2) An abstract of agricultural statistics of the Union of South Africa. Division of Agricultural Marketing Research, Pretoria. May, 1958.
- (3) Union statistics for fifty years. 1910 - 1960. Bureau of Census and Statistics, Pretoria. March, 1960.
- (4) Agricultural census reports. Bureau of Census and Statistics.
- (5) Reports on the "Transfers of rural and immovable property". Bureau of Census and Statistics.
- (6) Unofficial records.

Quantity series for South Africa were obtained from unpublished records of the Division of Agricultural Marketing Research, Pretoria. Provincial data were obtained from agricultural census reports. The Handbook of Agricultural Statistics 1904 - 1950, published by the Department of Agricultural Economics and Marketing, 1961 gives a summary of provincial data up to 1952. The average size of farms was derived from the "Transfer of rural and immovable property". Data were also obtained from O'Connell, J.A. (1965) "Die berekening van die bydrae van Landbou tot die binnelandse produk op 'n kwartaalbasis", M.A. dissertation, University of Pretoria; and Stadler, J.J. (1962) "Die bruto binnelandse produk van Suid-Afrika", D.Com. dissertation, University of Pretoria.