inclusive. However, for the intervening period (1918-19 through to 1931-2 inclusive), total salaries and wages figures were deficient in that they were shown only for the Southern Transvaal, Western Cape, Durban-Pinetown, and Port Elizabeth. A comparison of various years in which both a Union total and a "deficient" total were published revealed an average shortfall of approximately 15 per cent. For this period, therefore, the salaries figure was inflated by 15 per cent annually to obtain an approximate Union total. No statistics were published at all for the years 1918-19, 1925-6, 1930-1 and 1931-2, and had to be interpolated;

- for the whole industry, columns 1,2 and 3 include new railway, road, waterworks, and irrigation works construction from 1919-20 and for all later years, but exclude these for earlier years. Since the exclusion is common right across the columns it does not affect the average wage.

From these statistics it is possible to calculate the average earnings per employee and these are shown in column 4. Column 5 converts this to an index with 1938 base.

The calculation of price deflators for the pre-1946 period is performed in worksheet VIII. Column 1 reproduces the wholesale price index for metals from worksheet V, and column 2 reproduces the index of labour costs in the engineering and metal working industries from worksheet VI. It is now necessary to weight them in order to create a composite index which will be used as the price deflator for transport equipment, and machinery and other equipment. An analysis of columns 2 and 3 in worksheet VI reveals that, on average, the breakdown between materials and wages is of the order of 56 per cent, and 44 per cent respectively. Consequently, these are the weights chosen. The resulting index is shown in column 3 with a 1938 base.

Worksheet VIII also reproduces, in column 4, the wholesale price index for building materials from worksheet V, and column 5 reproduces the index of labour costs in the building and construction industry from worksheet VII. Unfortunately, the former index stops at 1910 and the latter index at 1916, whereas they must both be taken back to 1901. After examination of the trends of both indices in these early years, and in view of the general economic conditions at that time, it was decided to trace both indices back to 1901 on the assumption of an annual 3 per cent inflation rate. On average this would not introduce any significant inaccuracy. In any case, the deflator for these early years is being used to deflate relatively small expenditures on residential buildings only, so the relative cumulative inaccuracy would be insignificant. It is now necessary to weight the two indices in order to create a composite index which will be used as the price deflator for residential buildings, and non-residential buildings and construction works. An analysis of columns 2 and 3 in worksheet VII reveals that, on average, the breakdown between materials and wages is of the order of 60 per cent, and 40 per cent respectively. Consequently, these are the weights chosen. The resulting index is shown in column 6 with a 1938 base.

The price deflator in column 3 is used to deflate expenditures on both transport equipment and machinery and other equipment for the pre-1946 period. It is spliced into the indices in worksheet IV with a 1975 base, to take the index for transport equipment back to 1942 and the index for machinery and other equipment back to 1934. Likewise, the price deflator in column 6 is used to deflate expenditures on both residential buildings and non-residential buildings and construction works for the pre-1946 period. It also is spliced into the indices in worksheet IV with a 1975 base, to take the index for residential buildings back to 1900 and the index for non-residential buildings and construction works back to 1920. These early indices are shown in worksheet IX.

Real Capital Expenditure in the Coal Mining Industry: 1901-80

It is now necessary to convert the annual expenditures on the different types of capital assets from current prices (as shown in worksheets II and III) into constant 1975 prices. This is achieved by dividing the current expenditure by the relevant price deflator (as shown in worksheets IV and IX). The resulting real expenditures according to type of capital asset are shown in worksheet X.

Fixed Capital Stock in the Coal Mining Industry: 1950-80

The stage has now been reached where it is possible to calculate the fixed capital stock, measured at constant 1975 prices, for every year over the period 1950-80. Assets are not depreciated in value for reasons explained in the text. Thus, they are kept in at their deflated original cost for the average service life corresponding to their type of asset. For example, the expenditure of R0,3 million on residential buildings in 1901 remains in at that value until retired suddenly at the end of 1950. Correspondingly, the figure of R0,4 million for 1902 is retired at the end of 1951, and so on. The same argument (although with different service lives) applies to the other categories of capital assets.

Annual capital-stock figures for each of the types of capital assets can be calculated from worksheet X by cumulating previous expenditures for the number of years corresponding to the average service life of the asset. Thus 1950 capital stock for residential buildings is the sum of all expenditures from 1901 to 1950 inclusive; the 1951 capital stock is the sum of all expenditures from 1902 to 1951 inclusive; and so on, until 1980 is reached, each year adding in the latest expenditure and subtracting the oldest. The computations for the other types of assets are similar. Thus, the 1950 capital-stock figure for non-residential buildings and construction works is the sum of all expenditures from 1921 to 1950 inclusive, and so on for subsequent years. The fixed capital stock at constant 1975 prices according to type of asset is shown annually for the period 1950-80 in worksheet XI.

Worksheet XII reproduces the total capital-stock figures, as well as showing additional calculations of capital stock, firstly, excluding residential buildings, and, secondly, excluding residential buildings and non-residential buildings and construction works. These three separate definitions are then converted to indices with a 1950 base.

WORKSHEET I
COMPONENTS OF GROSS CAPITAL EXPENDITURE

RESIDENTIAL BUILDINGS

Residential Buildings: whites
Residential Buildings: non-whites
40 per cent of X[1]

NON-RESIDENTIAL BUILDINGS AND CONSTRUCTION WORKS

1950-69	1970-80
Amenities	Non-Residential Buildings
Housing of Plant	Railways and Roads
Offices and Stores	Other Construction
Railways	Mining Operations
Roads	50 per cent of Erection of Plant and Machinery
Other Buildings	60 per cent of X[1]
Shaft and Mine Development	
60 per cent of X[1]	

[1]Note: X = Building and Road-Making Materials: cement and concrete: piping and tubing, etc: timber, excluding sleepers and support of workings. These items are capitalised since a personal survey of several coal mines revealed that such materials are mainly used for additional structures, or to add to existing structures, rather than for maintenance and repairs.

TRANSPORT EQUIPMENT

Complete units only of:

- Locomotives
- Locomotives - other than electrical
- Scrapers, Haulages, Loaders, and Winches
- Trucks and Hoppers
- Vehicles, Aircrafts, and Boats

MACHINERY AND OTHER EQUIPMENT

Belting and Requisites

Electrical Equipment: Cables and Wires
Lamps
other

Electrical Machinery: complete units only:
Coal-Cutting Machines
Coal drills
Generators
Lifts
Motors
Switchgear and starters
Transformers
Winders
Other

Furniture and Office Equipment

Iron and Steel: Rail Accessories
Ropes (including stainless steel)
Rope Fittings
Rails

Machinery and Plant: complete units only:
Boilers and Economisers
Coal-Cutting Machines
Coal Drills
Compressors
Condensors
Conveyors & Elevators
Coolers (water)
Cranes, Crawls, and chain blocks
Diamond & other Borehole Drills
Detachable Bit Plant
Drill Sharpeners & Furnaces
Fans
Feeders and Stokers
Fire-Fighting Appliances
Headgears & Shaft Equip.
Instruments
Machine Tools
Motors & Stationery Engines
Pumps

Reduction Plant -

(i) Crushers
(ii) Vibrators
(iii) Stamp Milling
(iv) Tube Mills
(v) Agitators, Classifiers, Thickeners & Cyclones
(vi) Excavators & Distributors
(vii) Filters
(viii) Ion Exchange Equipment
(ix) Tanks
(x) Crowe-Merrill Plant
(xi) Flotation
(xii) All other

Rockdrills
Skips and Cages
Tipplers
Turbines Steam
Ventilation, Cooling and Air Conditioning Plants
Washing and Screening Plants
Water-Purification Plants
Winders
Other
Timber: Sleepers
Support of Workings
Tools: Abrasive
Brushware
Screwing and Cutting
Shovels
Other
50 per cent of Erection of Plant and Machinery (1970-80)

WORKSHEET II: GROSS INVESTMENT IN THE COAL MINING INDUSTRY, 1950-80, BY TYPE OF CAPITAL EXPENDITURE

(In millions of Rands)

YEAR / CATEGORY	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
Residential Buildings	0,61	0,44	0,47	0,51	0,36	0,38	0,51	0,47	0,44	0,44	0,57	0,78	0,77	1,07	1,77
Non-Residential Buildings and Construction Works	2,40	1,63	1,85	2,55	1,65	0,78	1,54	1,88	2,47	1,51	1,63	2,34	2,28	1,57	5,09
Transport Equipment	0,33	0,36	0,46	0,33	0,38	0,40	0,55	0,46	0,47	0,51	0,52	0,73	0,66	0,90	1,14
Machinery and Other Equipment	2,57	2,34	2,50	2,8[illegible]	3,32	2,49	3,22	3,71	4,17	4,03	4,32	6,59	5,83	7,03	8,79
TOTAL	5,91	4,77	5,2[illegible]	6,25	5,71	4,05	5,92	6,52	7,59	6,49	7,04	10,44	9,54	10,57	16,79

YEAR / CATEGORY	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Residential Buildings	1,47	0,88	1,45	1,07	2,11	1,83	1,53	1.64	1,27	3,91	6,71	10,68	15,54	10,23	12,87	20,51
Non-Residential Buildings and Construction Works	3,77	3,18	3,57	2,87	3,51	4,92	3,24	3,93	2,85	6,94	20,71	16,50	50,93	18,81	25,70	37,66
Transport Equipment	1,61	1,23	1,46	1,09	1,39	2,39	1,70	1,74	1,83	2,92	6,52	12,02	12,30	14,70	9,54	13,10
Machinery and Other Equipment	9,51	9,15	9,84	10,29	11,37	15,45	11,74	11,73	11,61	23,51	54,36	57,80	109,22	95,91	91,64	160,80
TOTAL	16,36	14,44	16.32	15,32	18,38	24,60	18,21	19,04	17,56	37,28	88,30	97,00	187,99	139,65	139,75	232,07

WORKSHEET III: GROSS INVESTMENT IN THE COAL MINING INDUSTRY, 1901-50, BY TYPE OF CAPITAL EXPENDITURE

(In millions of Rands)

YEAR CATEGORY	49	48	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33
Transport Equipment	0,31	0,28	0,38	0,19	0,19	0,19	0,18										
Machinery and Other Equipment	2,33	2,28	1,90	2,03	1,37	1,23	1,10	1,00	0,90	0,81	0,88	0,79	0,81	0,74	0,78		
Non-Residential Buildings and Construction Works	2,01	1,52	1,21	1,17	0,74	0,64	0,52	0,46	0,45	0,40	0,40	0,37	0,36	0,31	0,30	0,22	0,21
Residential Buildings	0,95	0,43	0,64	0,67	0,26	0,22	0,18	0,16	0,16	0,14	0,14	0,13	0,12	0,11	0,10	0,03	0,07

YEAR CATEGORY	32	31	30	29	28	27	26	25	24	23	22	21	20	19	18
Transport Equipment															
Machinery and Other Equipment															
Non-Residential Buildings and Construction Works	0,18	0,26	0,27	0,30	0,33	0,32	0,31	0,30	0,32	0,31	0,31	0,48			
Residential Buildings	0,06	0,09	0,09	0,10	0,11	0,11	0,11	0,10	0,11	0,11	0,11	0,17	0,14	0,12	0,10

YEAR	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	0,09	0,07	0,06	[illegible]	0,06	0,05	0,05	0,04	0,04	0,03	0,03	0,04	0,04	0,05	0,05	0,03	0,02

WORKSHEET IV: PRICE INDICES ACCORDING TO THE TYPE OF CAPITAL EXPENDITURE: 1946-80: 1975=100

CATEGORY YEAR	Residential Buildings	Non-R dential Bu ings	(Non-Residential Buildings and Construction Works)	Construction Works	Transport Equipment	Machinery and Other Equipment
46	23,0	21,7	(22,5)	22,9	26,1	22,6
47	25,1	24,4	(24,8)	25,0	28,2	24,7
48	26,3	25,3	(26,0)	26,4	31,0	26,7
49	27,6	26,6	(27,3)	27,6	33,1	28,8
50	29,5	28,5	(29,2)	29,6	38,8	33,5
51	34,0	32,8	(33,7)	34,1	44,6	38,2
52	37,5	36,1	(37,2)	37,8	49,3	42,3
53	37,0	35,6	(36,7)	37,3	47,9	41,7
54	36,0	34,9	(35,7)	36,1	47,4	41,0
55	36,9	35,6	(36,5)	37,0	47,9	41,6
56	38,1	37,0	(37,9)	38,3	48,6	42,5
57	38,3	37,0	(38,0)	38,5	50,0	43,6
58	38,8	37,5	(38,4)	38,9	49,6	44,3
59	39,5	38,1	(39,0)	39,5	51,4	44,7
60	37,8	37,7	(39,9)	41,0	51,4	44,9
61	37,7	37,7	(40,0)	41,1	51,9	45,3
62	39,0	38,9	(41,1)	42,2	52,9	46,2
63	40,3	39,8	(42,3)	43,5	53,9	46,8
64	42,2	41,5	(43,8)	45,0	54,7	47,6
65	45,1	44,4	(46,3)	47,3	55,0	48,7
66	48,0	47,9	(48,6)	49,0	56,8	51,6
67	50,4	50,6	(51,3)	51,6	57,7	52,2
68	51,9	52,2	(52,5)	52,6	59,0	52,3
69	52,3	52,8	(53,1)	53,2	61,5	54,0
70	55,9	56,3	(56,0)	55,8	63,3	56,6
71	58,9	58,9	(58,6)	58,4	68,1	59,8
72	63,7	63,7	(63,7)	63,7	72,8	67,4
73	72,3	72,3	(72,0)	71,8	76,8	73,1
74	82,8	83,0	(83,5)	83,7	83,7	83,4
75	100,0	100,0	(100,0)	100,0	100,0	100,0
76	115,6	116,1	(116,2)	116,3	116,4	117,8
77	126,0	126,6	(127,9)	128,6	128,3	127,4
78	140,4	140,1	(142,3)	143,4	141,8	141,2
79	161,3	159,4	(164,7)	167,3	158,8	159,2
80	189,8	188,2	(194,0)	196,9	177,4	176,8

WORKSHEET V: INDEX OF WHOLESALE PRICES: 1938=100

YEAR	METALS	BUILDING MATERIALS
1946	160,3	187,0
1945	162,4	187,4
1944	167,6	189,4
1943	170,8	185,0
1942	169,2	170,8
1941	154,3	150,1
1940	129,2	126,8
1939	99,5	101,3
1938	100,0	100,0
1937	97,6	99,8
1936	77,6	93,4
1935	75,5	94,7
1934	75,8	94,2
1933	74,7	92,6
1932	69,1	90,8
1931		98,0
1930		103,2
1929		103,3
1928		105,0
1927		107,3
1926		107,1
1925		108,7
1924		115,5
1923		123,6
1922		136,4
1921		174,2
1920		204,6
1919		174,4
1918		173,6
1917		146,7
1916		117,2
1915		100,0
1914		91,0
1913		88,6
1912		78,9
1911		86,5
1910		83,7
1909		
1908		
1907		
1906		
1905		
1904		
1903		
1902		
1901		

Source: Union Statistics for 50 years: 1910-59, Dept. of Statistics

WORKSHEET VI: ENGINEERING AND METAL WORKING INDUSTRIES

YEAR	(1) Average Number of Employees (in thousands)	(2) Total Salaries and Wages (in £ millions)	(3) Cost of Materials Used (in £ millions)	(4) Ave. Earnings per employee (£'s)	(5) Index 1938= 100
33-34	40,7	5,6	7,4	137,6	92,7
34-35	48,2	6,9	9,1	143,2	96,4
35-36	57,1	8,1	10,5	141,9	95,6
36-37	62,2	9,0	13,2	144,7	97,4
37-38	66,0	9,8	14,2	148,5	100
38-39	66,1	9,9	13,8	149,8	100,9
39-40	72,6	10,9	15,5	150,1	101,1
40-41	79,1	13,0	18,7	164,3	110,6
41-42	85,6	15,8	19,1	184,6	124,3
42-43	92,1	18,3	17,7	198,7	133,8
43-44	98,9	20,2	20,7	204,2	137,5
44-45	103,0	23,0	24,4	223,3	150,4
45-46	107,0	24,0	27,0	224,3	151,0

Source: Official Yearbook of the Union of South Africa, printed annually

WORKSHEET VII: BUILDING AND CONSTRUCTION INDUSTRY

YEAR	(1) Average Number of Employees (in thousands)	(2) Total Salaries and Wages (in £ millions)	(3) Cost of Materials Used (in £ millions)	(4) Ave. Earnings per Employee (in £'s)	(5) Index 1938= 100
45-46	40,8	7,6	10,9	186,3	137,1
44-45	34,5	6,3	7,4	182,6	134,4
43-44	30,4	5,2	6,2	171,1	125,9
42-43	32,0	5,3	5,7	165,6	121,9
41-42	37,1	5,8	8,3	156,3	115,0
40-41	35,1	4,6	8,0	131,1	96,5
39-40	35,2	4,7	7,7	133,5	98,2
38-39	38,4	5,1	8,3	132,8	97,7
37-38	41,2	5,6	8,8	135,9	100
36-37	39,1	5,2	8,8	133,0	97,9
35-36	33,6	4,3	6,8	128,0	94,2
34-35	26,8	3,2	5,2	119,4	87,9
33-34	18,3	2,0	3,5	109,3	80,4
32-33	11,1	1,2	1,8	108,1	79,5
31-32	17,1	2,0	2,8	117,0	86,1
30-31	22,7	2,7	3,9	118,9	87,5
29-30	28,3	3,4	4,9	120,1	88,4
28-29	28,3	3,1	4,6	109,5	80,6
27-28	29,6	3,2	4,7	108,1	79,5
26-27	31,4	3,3	4,5	105,1	77,3
25-26	32,7	3,2	4,1	97,9	72,0
24-25	34,0	3,2	3,7	94,1	69,2
23-24	34,1	3,2	3,6	93,8	69,0
22-23	28,6	2,4	3,5	83,9	61,7
21-22	29,2	2,3	3,3	78,8	58,0
20-21	31,8	2,6	4,4	81,8	60,2
19-20	28,3	2,1	3,4	74,2	54,6
18-19	12,2	1,1	1,6	90,2	66,4
17-18	12,2	1,1	1,6	90,2	66,4
16-17	12,8	0,9	1,4	70,3	51,7
15-16	8,6	0,7	1,1	81,4	59,9
14-15					
13-14					
12-13					
11-12					
10-11					
9-10					
8-9					
7-8					
6-7					
5-6					
4-5					
3-4					
2-3					
1-2					
0-1					

Source: Official Yearbook of the Union of South Africa, printed annually

WORKSHEET VIII: CALCULATION OF PRICE DEFLATORS: PRE-1946

YEAR	(1) Index of Metals Weight= 0,56	(2) Index of Average Earnings/ Employee Weight= 0,44	(3) Price Deflator for Transport Equipment, and Machinery and Other Equipment	(4) Index of Building Materials Weight= 0,6	(5) Index of Average Earnings/ Employee Weight= 0,4	Price Deflator for Residential Bldgs, and non-Resid. Bldgs, and Construct. Works
1946	160,3	151,0	156,2	187,0	137,1	167,0
1945	162,4	150,4	157,1	187,4	134,4	166,2
1944	167,6	137,5	154,4	189,4	125,9	164,0
1943	170,8	133,8	154,5	185,0	121,9	159,8
1942	169,2	124,3	149,4	170,8	115,0	148,5
1941	154,3	110,6	135,1	150,1	96,5	128,7
1940	129,2	101,1	116,8	126,8	98,2	115,4
1939	99,5	100,9	100,1	101,3	97,7	99,9
1938	100	100	100	100	100	100
1937	97,6	97,4	97,5	99,8	97,9	99,0
1936	77,6	95,6	85,5	93,4	94,2	93,7
1935	75,5	96,4	84,7	94,7	87,9	92,0
1934	75,8	92,7	83,2	94,2	80,4	88,7
1933				92,6	79,5	87,4
1932				90,8	86,1	88,9
1931				98,0	87,5	93,8
1930				103,2	88,4	97,3
1929				103,3	80,6	94,2
1928				105,0	79,5	94,8
1927				107,3	77,3	95,3
1926				107,1	72,0	93,1
1925				108,7	69,2	92,9
1924				115,5	69,0	96,9
1923				123,6	61,7	98,8
1922				136,4	58,0	105,0
1921				174,2	60,2	128,6
1920				204,6	54,6	144,6
1919				174,4	66,4	131,2
1918				173,6	66,4	130,7
1917				146,7	51,7	108,7
1916				117,2	59,9	94,3
1915				100,0	58,1	83,2
1914				91,0	56,4	77,2
1913				88,6	54,7	75,0
1912				78,9	53,0	68,5
1911				86,5	51,4	72,5
1910				83,7	49,9	70,2
1909				81,2	48,4	68,1
1908				78,8	46,9	66,0
1907				76,4	45,5	64,0
1906				74,1	44,2	62,1
1905				71,9	42,8	60,3
1904				69,7	41,6	58,5
1903				67,6	40,3	56,7
1902				65,6	39,1	55,0
1901				63,6	37,9	53,3
1900				61,7	36,8	51,7

WORKSHEET IX: PRICE INDICES ACCORDING TO TYPE OF CAPITAL EXPENDITURE: PRE-1946 1975=100

CATEGORY YEAR	Residential Buildings	Non-Residential Bldgs & Construction Works	Transport Equipment	Machinery & Other Equipment
1900	7,1			
1901	7,3			
1902	7,6			
1903	7,8			
1904	8,1			
1905	8,3			
1906	8,6			
1907	8,8			
1908	9,1			
1909	9,4			
1910	9,7			
1911	10,0			
1912	9,4			
1913	10,3			
1914	10,6			
1915	11,5			
1916	13,0			
1917	15,0			
1918	18,0			
1919	18,1			
1920	19,9	19,5		
1921	17,7	17,3		
1922	14,5	14,1		
1923	13,6	13,3		
1924	13,3	13,1		
1925	12,8	12,5		
1926	12,8	12,5		
1927	13,1	12,8		
1928	13,1	12,8		
1929	13,0	12,7		
1930	13,4	13,1		
1931	12,9	12,6		
1932	12,2	12,0		
1933	12,0	11,8		
1934	12,2	12,0		12,1
1935	12,7	12,4		12,3
1936	12,9	12,6		12,4
1937	13,6	13,3		14,1
1938	13,8	13,5		14,5
1939	13,8	13,5		14,5
1940	15,9	15,5		16,9
1941	17,7	17,3		19,5
1942	20,5	20,0	25,0	21,6
1943	22,0	21,5	25,9	22,3
1944	22,6	22,1	25,9	22,3
1945	22,9	22,4	26,3	22,7
1946	23,0	22,5	26,1	22,6

WORKSHEET X: GROSS INVESTMENT IN THE COAL MINING INDUSTRY, 1901-80, BY TYPE OF CAPITAL EXPENDITURE (AT CONSTANT 1975 PRICES)
(millions of Rands)

CATEGORY YEAR	Residential Buildings	Non-Residential Blgs & Construction Works	Transport Equipment	Machinery & Other Equipment
1900	-			
1901	0,3			
1902	0,4			
1903	0,6			
1904	0,6			
1905	0,5			
1906	0,5			
1907	0,3			
1908	0,3			
1909	0,4			
1910	0,4			
1911	0,5			
1912	0,5			
1913	0,6			
1914	0,6			
1915	0,5			
1916	0,5			
1917	0,6			
1918	0,6			
1919	0,7			
1920	0,7			
1921	1,0	2,8		
1922	0,8	2,2		
1923	0,8	2,3		
1924	0,8	2,4		
1925	0,8	2,4		
1926	0,9	2,5		
1927	0,8	2,5		
1928	0,8	2,6		
1929	0,8	2,4		
1930	0,7	2,1		
1931	0,7	2,1		
1932	0,5	1,5		
1933	0,6	1,8		
1934	0,7	1,8		
1935	0,8	2,4		6,3
1936	0,9	2,5		6,0
1937	0,9	2,7		5,7
1938	0,9	2,7		5,4
1939	1,0	3,0		6,1
1940	0,9	2,6		4,8
1941	0,9	2,6		4,6
1942	0,8	2,3		4,6
1943	0,8	2,4	0,7	4,9
1944	1,0	2,9	0,7	5,5
1945	1,1	3,3	0,7	6,0
1946	2,9	5,2	0,7	9,0
1947	2,5	4,9	1,3	7,7
1948	1,6	5,8	0,9	8,5
1949	3,4	7,4	0,9	8,1

WORKSHEET X: Continued

CATEGORY YEAR	Residential Buildings	Non-Residential Blgs & Construction Works	Transport Equipment	Machinery & Other Equipment
1950	2,1	8,2	0,9	7,7
1951	1,3	4,8	0,8	6,1
1952	1,3	5,0	0,9	5,9
1953	1,4	6,9	0,7	6,9
1954	1,0	4,6	0,8	8,1
1955	1,0	2,1	0,8	6,0
1956	1,3	4,1	1,1	7,6
1957	1,2	4,9	0,9	8,5
1958	1,1	6,4	0,9	9,4
1959	1,1	3,9	1,0	9,0
1960	1,5	4,1	1,0	9,6
1961	2,1	5,9	1,4	14,5
1962	2,0	5,5	1,2	12,6
1963	2,7	3,7	1,7	15,0
1964	4,2	11,6	2,1	18,5
1965	3,3	8,1	2,9	19,5
1966	1,8	6,5	2,2	17,7
1967	2,9	7,0	2,5	18,9
1968	2,1	5,5	1,8	19,7
1969	4,0	6,6	2,3	21,1
1970	3,3	8,8	3,8	27,3
1971	2,6	5,5	2,5	19,6
1972	2,6	6,2	2,4	17,4
1973	1,8	4,0	2,4	15,9
1974	4,7	8,3	3,5	28,2
1975	6,7	20,7	6,5	54,4
1976	9,2	14,2	10,3	49,1
1977	12,3	39,8	9,6	85,7
1978	7,3	13,2	10,4	67,9
1979	8,0	15,6	6,0	57,6
1980	10,8	19,4	7,4	91,0

WORKSHEET XI: FIXED CAPITAL STOCK IN THE COAL MINING INDUSTRY, 1950-80, BY TYPE OF ASSET (AT CONSTANT 1975 PRICES)
(millions of Rands)

CATEGORY YEAR	Non-Residential Blgs & Construction Works	Residential Buildings	Transport Equipment	Machinery & Other Equipment	Total
1950	92,3	43,3	6,8	100,9	243,3
1951	94,3	44,3	6,9	100,7	246,2
1952	97,1	45,2	7,1	100,6	250,0
1953	101,7	46,0	7,1	101,8	256,6
1954	103,9	46,4	7,2	104,5	262,0
1955	103,6	46,9	6,7	104,4	261,6
1956	105,2	47,7	6,9	107,2	267,0
1957	107,6	48,6	6,9	111,1	274,2
1958	111,4	49,4	6,9	115,9	283,6
1959	112,9	50,1	7,1	120,0	290,1
1960	114,9	51,2	7,2	124,1	297,4
1961	118,7	52,8	7,9	132,6	312,0
1962	122,7	54,3	8,3	136,2	321,5
1963	124,6	56,4	9,2	143,5	333,7
1964	134,4	60,0	10,2	153,5	358,1
1965	140,1	62,8	12,2	164,9	380,0
1966	144,1	64,1	13,5	174,9	396,6
1967	148,4	66,4	15,0	187,7	417,5
1968	151,2	67,9	15,8	201,5	436,4
1969	154,8	71,2	16,7	215,7	458,4
1970	161,0	73,8	19,3	234,9	489,0
1971	163,9	75,4	20,1	248,5	507,9
1972	167,8	77,2	20,4	258,3	523,7
1973	169,4	78,2	19,9	265,7	533,2
1974	174,8	82,1	21,2	284,5	562,6
1975	192,2	88,0	25,2	329,9	635,3
1976	201,2	96,3	33,7	369,4	700,6
1977	236,1	107,8	41,0	440,6	825,5
1978	243,5	114,3	47,6	495,9	901,3
1979	251,7	121,5	51,1	538,5	962,8
1980	262,9	131,6	56,1	611,0	1061,6

WORKSHEET XII: FIXED CAPITAL STOCK IN THE COAL MINING INDUSTRY, 1950-80, (AT CONSTANT 1975 PRICES, MILLIONS OF RANDS)

YEAR	(1) TOTAL	(2) TOTAL Excluding Residential Buildings	(3) TOTAL Excluding Res. Bldgs, & Non-Res. Blgds & Constr. Works	INDICES: 1950=100 (1)	(2)	(3)
1950	243,3	200,0	107,7	100,0	100,0	100,0
1951	246,2	201,9	107,6	101,2	101,0	99,9
1952	250,0	204,8	107,7	102,8	102,4	100,0
1953	256,6	210,6	108,9	105,5	105,3	101,1
1954	262,0	215,6	111,7	107,7	107,8	103,7
1955	261,6	214,7	111,1	107,5	107,4	103,2
1956	267,0	219,3	114,1	109,7	109,7	105,9
1957	274,2	225,6	118,0	112,7	112,8	109,6
1958	283,6	234,2	122,8	116,6	117,1	114,0
1959	290,1	240,1	127,1	119,2	120,1	118,0
1960	297,4	246,2	131,3	122,2	123,1	121,9
1961	312,0	259,2	140,5	128,2	129,6	130,5
1962	321,5	267,2	144,5	132,1	133,6	134,2
1963	333,7	277,3	152,7	137,2	138,7	141,8
1964	358,1	298,1	163,7	147,2	149,1	152,0
1965	380,0	317,2	177,1	156,2	158,6	164,4
1966	396,6	332,5	188,4	163,0	166,3	174,9
1967	417,5	351,1	202,7	171,6	175,6	188,2
1968	436,4	368,5	217,3	179,4	184,3	201,8
1969	458,4	387,2	232,4	188,4	193,6	215,8
1970	489,0	415,2	254,2	201,0	207,6	236,0
1971	507,9	432,5	268,6	208,8	216,3	249,4
1972	523,7	446,5	278,7	215,2	223,3	258,8
1973	533,2	455,0	285,6	219,2	227,5	265,2
1974	562,6	480,5	305,7	231,2	240,3	283,8
1975	635,3	547,3	355,1	261,1	273,7	329,7
1976	700,6	604,3	403,1	288,0	302,2	374,3
1977	825,5	717,7	481,6	339,3	358,9	447,2
1978	901,3	787,0	543,5	370,4	393,5	504,6
1979	962,8	841,3	589,6	395,7	420,7	547,4
1980	1061,6	930,3	667,1	436,3	465,0	619,4

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(1) de Jager, B.L., "The Fixed Capital Stock and Capital-Output Ratio of South Africa from 1946 to 1972", S.A. Reserve Bank, Quarterly Bulletin, June 1973.

(2) Department of Mines, Annual Report, published annually, see statistics relating to "stores consumed"; Government Printer, Pretoria.

(3) Department of Mines, Reference Key and Alphabetical Index to Stores Return, M.D. 272, Government Printer, Pretoria: revised 1956 and 1975.

(4) Chamber of Mines of South Africa, Annual Report, published annually, see statistics relating to "Analysis of all Stores Consumed during the year by Gold and Coal Mines, Members of the Chamber", Johannesburg.

(5) Department of Mines, Mining Statistics, published annually, see statistics relating to "value of stores consumed"; Government Printer, Pretoria.

(6) "A Statistical Presentation of South Africa's National Accounts for the Period 1946 to 1980", Supplement to Quarterly Bulletin, Economics Department of the South African Reserve Bank, September 1981.

(7) Official Yearbook of the Union of South Africa, Union Office of Census and Statistics, printed annually, Government Printer, Pretoria: see chapter entitled "Manufacturing Industries".

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CHAPTER 9: APPENDIX B

DETERMINATION OF RAW MATERIALS INPUT

For the purpose of this thesis raw materials are defined very widely, namely, as comprising any item of stores not categorised as capital expenditure. For the most part, an item classified as a raw material is either used up immediately in the extraction process (for instance, explosives and electricity), or can be regarded as being exhausted within a time span of one year (for instance, protective clothing and boots, buckets, tyres and tubes, lubricating oils, and so on). As a result, the problem of average life spans does not arise - all raw materials are exhausted within the year. Hence, all raw materials expenditure for a given year can be directly related to the output level for that year with no "carry-over" effects from previous years or to subsequent years. The problem of depreciation is avoided.

With the above definition in mind, worksheet XIII details all the items which comprise raw materials in the coal mining industry. The items are as presented in the detailed breakdown of stores consumed, published in the Annual Reports of the Department of Mines (1), and the Chamber of Mines (2).

The calculation of the total value of raw materials consumed in any given year is simply the difference between the total value of stores and total capital expenditure for that year. Column 1 of worksheet XIV shows the total value of stores consumed in the South African coal mining industry over the period 1950-80. The data for the years 1950-77 inclusive are Department of Mines' figures (3), but these are virtually identical to those published by the Chamber of Mines. Data for the years 1978-80 inclusive are Chamber of Mines' figures which exclude the newly-established collieries of Rietspruit, Duvha, and Grootegeluk. Consequently, for these years, the Department's total stores are well above the Chamber's, but since only the latter source provides a detailed breakdown of stores for these years, these are the figures which are adopted. Such an approach is consistent with the capital-input measure in Appendix A.

Column 2 reproduces the figures for total capital expenditure previously calculated in worksheet II. The difference between the two columns gives the total value of raw materials, shown as column 3. For the period 1970-80, raw materials are the straight difference between the two columns since the item "mining operations" was included in total stores. However, for the period 1950-69, the item "shaft and mine development" was not included in total stores but quoted separately in the Department of Mines' Annual Reports, and forms part of total capital expenditure in this thesis. Therefore, for these years, "shaft and mine development" must be added to total stores before capital expenditure is deducted.

Raw materials are quoted in terms of prices ruling when the expenditure was incurred and must be deflated to constant prices to obtain a volume series. Due to the wide variety of items comprising the raw materials input the deflator chosen is the wholesale price index (all groups), as calculated and published by the Department of Statistics (4). This is shown as column 4, re-calculated and linked-in, with a 1950 base. The consequent value of raw materials in constant 1950 prices is shown as column 5, and this is reduced to an index with 1950 base in column 6.

More-Sophisticated Calculation of Raw Material Input

The above method of calculating raw material input can be regarded as unsophisticated. A more-accurate method suggests itself once it is realised that certain components of raw materials can be directly measured in physical units. The major ones are: bolts, nuts, rivets, and washers (kilograms); explosives (cases); detonators (number); meat (kilograms); other foodstuffs (kilograms); fuel and power oil (litres); lubricating oils and greases (litres); and electricity (kilowatt hours). Spares and repairs to machinery, electrical machinery, plant, and transport equipment can be measured in current rands; and the remainder of the raw material input can also be measured in current rands.

Worksheet XV shows the magnitude of these respective raw materials inputs for the study period 1950-80. The data is calculated from the detailed breakdown of stores consumed, published in the Department of Mines' and Chamber of Mines' Annual Reports. With reference to these sources the remarks made in Appendix A in regard to the capital-input variable are also applicable at this stage. The only additional problem encountered here concerns the non-reportage of electricity measured in kilowatt hours for Transvaal and Orange Free State coal mines for the period 1950-53 inclusive, and for Natal coal mines for the period 1950-56 inclusive. The relatively-low figures for these periods can, however, be reasonably well estimated by interpolation, and by way of comparison with the reported values of electricity consumed and total coal outputs produced.

The only columns which are not reported in physical units, namely, the value of spares and repairs, and the value of the remainder of raw materials, must now be deflated to constant prices by appropriate price indices in order to convert them to volume terms and, hence, make them comparable with the other columns.

With regard to spares and repairs, the reporting of the value of this item tends to differ between coal mines. Many mines report only the cost of the spare parts involved, particularly as they repair the bulk of their equipment with their own skilled personnel on the premises. Other mines, however, particularly those utilising expensive and complex machinery, report a labour service charge in addition to the cost of spare parts, since they frequently rely on external assistance in the repair and maintenance of equipment. Official statistical agencies in South Africa do not compile a specific price deflator for spares and repairs to equipment. The Department of Statistics is of the opinion that such an index is unnecessary since it would closely mirror the trend of a price index for overall plant, machinery, and equipment. A composite price index for machinery and equipment compiled by the Reserve Bank from information supplied by the Department of Statistics (with pure price components being adjusted for measurable changes in labour productivity) has already been employed in Appendix A for the deflation of investment expenditure on this item in the calculation of the capital-input measure. It is reproduced in worksheet XVI, as column 1, re-calculated with a 1950 base, and could be conveniently used as a proxy index for the deflation of expenditure on spares and repairs.

Another possibility is presented in the form of statistics compiled by the Division of Agricultural Marketing Research of the Department of Agricultural Economics and Marketing (5) and also published by the Department of Statistics (6). Until 1979 they compiled an index of the cost of spare parts to the farming industry. These spare parts were overwhelmingly for use in lorries, tractors, implements (ploughs, etc.), and pumping and irrigation equipment. Although the type, range, and complexity of equipment and spare parts in the farming industry is not comparable with coal mining, such an index is, nevertheless, instructive. It is presented as column 2 in worksheet XVI with a 1950 base. A price index relating to repair service charges is also compiled for the farming industry and is presented as column 3. In combining these two indices for various purposes, both the Division of Agricultural Marketing Research and the Department of Statistics employ weights of approximately 5,8:1. Using these weights columns 2 and 3 are combined to obtain a price index for spares and repairs in the farming industry and this is presented as column 4.

In comparing columns 1 and 4, a strong similarity is noticed in the trend and movement of the two indices, in other words, an overall price index for machinery and equipment closely resembles a price index for spares and repairs in the farming industry. It appears, therefore, that the opinion of the Department of Statistics may be substantially correct, and there is no reason to suspect why a price index for spares and repairs in the coal mining industry should show any major differences. Consequently, the index shown in column 1 is employed for the necessary deflation, and the deflated values for spares and repairs are shown as column 1 in worksheet XVII at constant 1950 prices.

With regard to the value of the remainder of raw materials this category includes a wide variety of materials such as castings, items of iron and steel, chemicals, clothing, disinfectants, foundry requisites, hospital requisites, lubricators, paints, paper and stationery, plastic and rubber goods, sand and stone, soaps and polishes, wire, transport and railage, compressed air, water, and many other items. In view of the large variety of items covered, the only valid procedure is to deflate the total value of these items by the overall wholesale price index as already presented in worksheet XIV. These deflated values are shown as column 2 in worksheet XVII with constant 1950 prices.

All the separate items of raw materials have now been reduced to volume terms and, hence, can be represented in index form. These indices are shown in worksheet XVIII with a 1950 base.

The ten separate indices can now be combined into a composite index to show the movement of the consumption of the volume of raw materials in the coal mining industry over the study period. For this purpose appropriate weighting of each index is required according to the importance of each item. Weighting is performed according to the percentage of the overall value of raw materials accounted for by each separate item. Over the study period these relative weights have changed, as is shown in table 9B.1.

In view of the trends of the relative importance of each of the separate items comprising the raw materials input, an updating of the weights every five years appeared to be a reasonable approach, and this necessitated a simultaneous update in the base year in the construction of the aggregate raw material index. By a linking procedure, the long-term composite index for the volume of raw materials consumed was constructed with a 1950 base. This is shown in worksheet XIX.

Although this more-sophisticated index has been constructed by a technically more-correct procedure than the index constructed in worksheet XIV, the two indices display remarkably similar trends and movements.

TABLE 9B.1 WEIGHTING STRUCTURE ADOPTED IN COMPILATION OF RAW MATERIALS INDEX

YEAR	Bolts, Nuts Rivets and Washers	Explosives	Detonators	Meat	Other Foodstuffs	Fuel and Power Oil	Lubricating Oils and Greases	Electricity	Spares and Repairs	Remainder of Raw Materials
1950	1	9	3	9	17	0	6	8	12	35
1955	1	9	3	7	14	0	5	9	16	36
1960	2	7	4	7	11	0	4	10	19	36
1965	4	6	4	6	11	0	3	10	24	32
1970	5	6	4	5	7	1	3	10	29	30
1975	5	7	3	5	5	2	3	8	37	25
1980	4	4	3	2	3	5	3	10	43	23

WORKSHEET XIII: ITEMS COMPRISING RAW MATERIALS IN THE SOUTH AFRICAN COAL MINING INDUSTRY

Assay, laboratory and smelting goods
Bolts, nuts, rivets, and washers
Brake linings
Buckets, cans, etc.
Candles
Carbide
Castings
Chain
Chemicals: all
Clothing: boots, jackets, other
Cloth, canvas, and other textiles
Coal
Coke
Charcoal
Cordage
Disinfectants
Electrical Machinery and spares:
  spares and repairs only
Explosives, detonators, safety fuse, etc.
Foodstuffs, supplied free: all employees
Foundry and other shop requisites
Hose
Hose fittings
Hospital and ambulance requisites
Iron and Steel: all - except rails,
  rail accessories, ropes and rope
  fittings
Lamps (other than electrical)
Lime
Locks, hinges, and ironmongery
Lubricators
Machinery and plant: bearings,
  spares and repairs, painting,
  tyres and tubes only.
Nails, screws, and pins
Non-ferrous metals: all
Oils, greases, and fuel oil
Packings and jointings
Paints, driers, etc.
Paper, stationery, and printing
Plastics and rubber goods
Sand, stone, and mineral rock
Soaps and polishes
Stables, animals, and requisites
Wire
Wire screening
Sundries
Land improvement
and development
Transport and railage
Compressed Air
Electricity
Water

WORKSHEET XIV: RAW MATERIALS IN THE SOUTH AFRICAN COAL MINING INDUSTRY: 1950-80

YEAR	(1) TOTAL VALUE OF STORES Rm	(2) TOTAL CAPITAL EXPENDITURE Rm	(3) TOTAL VALUE OF RAW MATERIALS Rm	(4) WHOLESALE PRICE INDEX 1950=100
1950	10,0	5,9	5,0	100,0
1951	10,0	4,8	5,8	114,3
1952	11,8	5,3	7,2	131,0
1953	13,0	6,3	8,2	132,3
1954	12,4	5,7	7,5	133,2
1955	12,0	4,1	8,2	137,4
1956	14,2	5,8	9,1	139,3
1957	16,2	6,5	10,8	141,4
1958	18,0	7,6	12,2	141,8
1959	20,4	6,5	14,8	141,6
1960	21,2	7,0	14,6	143,6
1961	26,7	10,4	17,6	145,9
1962	27,1	9,5	18,8	146,9
1963	29,1	10,6	18,9	148,9
1964	34,1	16,8	19,6	152,4
1965	36,2	16,4	21,9	157,0
1966	38,6	14,4	25,3	163,0
1967	43,8	16,3	28,7	167,0
1968	46,3	15,3	32,2	169,0
1969	47,1	18,4	29,9	172,8
1970	57,9	24,6	33,3	178,3
1971	53,0	18,2	34,8	186,6
1972	54,1	19,0	35,1	201,8
1973	60,1	17,6	42,5	228,4
1974	90,9	37,3	53,6	269,3
1975	166,1	88,3	77,8	315,9
1976	213,8	97,0	116,8	363,7
1977	347,3	188,0	159,3	410,8
1978	358,7	139,7	219,0	450,8
1979	390,6	139,8	250,8	519,6
1980	542,6	232,1	310,5	606,9

WORKSHEET XIV: Continued

YEAR	(5) RAW MATERIALS IN CONSTANT 1950 PRICES: Rm	(6) INDEX 1950=100
1950	5,0	100,0
1951	5,1	102,0
1952	5,5	110,0
1953	6,2	124,0
1954	5,6	112,0
1955	6,0	120,0
1956	6,5	130,0
1957	7,6	152,0
1958	8,6	172,0
1959	10,5	210,0
1960	10,2	204,0
1961	12,1	242,0
1962	12,8	256,0
1963	12,7	254,0
1964	12,9	258,0
1965	13,9	278,0
1966	15,5	310,0
1967	17,2	344,0
1968	19,1	382,0
1969	17,3	346,0
1970	18,7	374,0
1971	18,6	372,0
1972	17,4	348,0
1973	18,6	372,0
1974	19,9	398,0
1975	24,6	492,0
1976	32,1	642,0
1977	38,8	776,0
1978	48,6	972,0
1979	48,3	966,0
1980	51,2	1024,0

WORKSHEET XV: RAW MATERIALS INPUTS: SOUTH AFRICAN COAL MINING INDUSTRY: 1950-80

YEAR	Bolts, Nuts, Rivets and Washers	Explosives	Detonators	Meat	Other Foodstuffs	Fuel and Power Oil	Lubricating Oils and Greases	Electricity	Spares & Repairs to Machinery, Plant and Vehicles	Remainder of Raw Materials
	millions of kilograms	thousands of cases	millions	mill. of kg.	millions of kg.	millions of litres	millions of litres	millions of kilowatt hrs	millions of rands	millions of rands
1950	0,26	154	5,4	3,89	25,6	0,1	2,80	131	0,6	1,7
1951	0,25	157	6,2	3,95	26,2	0,1	2,84	145	0,7	2,1
1952	0,24	188	6,4	4,04	25,2	0,1	2,76	154	0,9	2,4
1953	0,26	180	7,5	3,62	24,8	0,2	2,93	165	1,2	3,2
1954	0,26	172	7,0	3,86	25,7	0,2	[illegible],00	160	1,2	2,4
1955	0,32	212	8,1	3,28	24,2	0,2	2,82	181	1,3	2,9
1956	0,34	222	7,9	3,70	29,3	0,3	3,21	190	1,6	2,9
1957	0,32	210	7,9	3,76	27,8	0,4	3,03	196	1,8	3,5
1958	0,48	224	8,3	4,14	29,6	0,4	3,43	213	1,9	4,3
1959	0,89	230	8,1	4,41	30,8	0,6	3,45	229	2,1	5,1
1960	1,21	247	9,1	4,54	30,4	0,9	3,77	246	2,6	5,2
1961	1,89	252	9,5	4,65	31,9	1,0	3,96	262	3,1	5,7
1962	1,46	264	9,9	5,11	32,0	1,3	4,25	284	3,3	5,9
1963	3,63	296	11,1	5,70	33,6	1,8	5,28	325	4,0	6,8
1964	3,94	322	11,9	5,34	34,1	2,3	5,13	383	4,2	6,8
1965	3,69	367	13,8	5,12	38,6	2,2	5,35	401	5,2	7,1
1966	3,33	355	13,2	5,00	33,6	2,5	4,86	407	5,4	7,8
1967	3,31	376	17,9	4,80	32,3	3,5	4,98	583	6,2	8,8
1968	4,14	399	14,5	4,68	32,8	3,0	5,55	480	7,5	9,8
1969	6,11	445	15,4	4,69	34,5	3,3	5,58	530	8,8	9,3
1970	8,49	479	15,5	4,61	32,5	4,3	6,05	560	9,6	10,0
1971	8,28	497	23,6	4,85	30,0	5,4	[illegible],60	595	11,1	10,1
1972	4,12	512	17,0	4,82	34,0	6,3	6,57	636	12,4	9,9
1973	5,87	562	17,4	4,64	35,4	8,1	7,08	676	15,1	11,1
1974	8,27	586	16,2	5,09	30,4	10,9	6,38	689	18,7	12,8
1975	10,79	669	18,3	4,77	32,7	12,6	8,22	773	28,8	19,4
1976	13,07	693	20,7	5,45	35,8	20,1	10,38	827	48,6	29,2
1977	8,42	820	23,6	5,66	35,7	27,6	11,29	1003	66,6	38,6
1978	12,74	978	26,0	6,44	36,3	30,3	13,24	1114	87,9	45,8
1979	9,40	966	24,7	6,49	38,4	38,0	19,54	1321	104,6	56,6
1980	12,71	1049	30,2	6,55	37,0	38,9	13,50	1400	132,8	69,2

WORKSHEET XVI: PRICE INDICES FOR THE DEFLATION OF SPARES AND REPAIRS

YEAR	(1) PRICE DEFLATOR FOR MACHINERY AND EQUIPMENT	(2) PRICE INDEX FOR SPARE PARTS IN THE FARMING INDUSTRY	(3) PRICE INDEX FOR REPAIR SERVICE CHARGES IN THE FARMING INDUSTRY	(4) PRICE INDEX FOR SPARES & REPAIRS IN THE FARMING INDUSTRY
1950	100,0	100,0	100,0	100,0
1951	114,0	116,4	103,5	114,5
1952	126,3	131,0	107,0	127,5
1953	124,5	138,8	110,5	134,6
1954	122,4	137,1	114,0	133,7
1955	124,2	137,9	117,0	134,8
1956	126,9	138,8	117,0	135,6
1957	130,1	144,0	117,0	140,0
1958	132,2	147,4	117,0	142,9
1959	133,4	149,1	117,0	144,4
1960	134,0	149,0	132,8	146,6
1961	135,2	149,2	141,1	148,0
1962	137,9	151,6	150,1	151,4
1963	139,7	152,7	160,1	153,8
1964	142,1	156,7	165,2	158,0
1965	145,3	164,5	175,8	166.2
1966	154,0	165,2	200,5	170,4
1967	155,8	165,2	218,8	173,1
1968	156,1	168,6	228,5	177,4
1969	161,2	172,7	247,4	183,7
1970	169,0	179,1	258,2	190,7
1971	178,5	182,3	285,9	197,5
1972	201,2	192,8	323,9	212,1
1973	218,2	203,8	354,8	226,0
1974	249,0	232,7	398,2	257,0
1975	298,5	277,5	458,0	304,0
1976	351,6	331,6	518,3	359,1
1977	380,3	344,4	565,5	376,9
1978	421,5	383,0	597,2	414,5
1979	475,2	438,8	665,6	472,2
1980	527,8	-	-	-

WORKSHEET XVII: DEFLATED VALUES OF SPARES AND REPAIRS AND REMAINDER OF RAW MATERIALS

YEAR	(1) SPARES AND REPAIRS at constant 1950 prices	(2) REMAINDER OF RAW MATERIALS at constant 1950 prices
1950	0,6	1,7
1951	0,6	1,8
1952	0,7	1,8
1953	1,0	2,4
1954	1,0	1,8
1955	1,0	2,1
1956	1,3	2,1
1957	1,4	2,5
1958	1,4	3,0
1959	1,6	3,6
1960	1,9	3,6
1961	2,3	3,9
1962	2,4	4,0
1963	2,9	4,6
1964	3,0	4,5
1965	3,6	4,5
1966	3,5	4,8
1967	4,0	5,3
1968	4,8	5,8
1969	5,5	5,4
1970	5,7	5,6
1971	6,2	5,4
1972	6,2	4,9
1973	6,9	4,9
1974	7,5	4,8
1975	9,6	6,1
1976	13,8	8,0
1977	17,5	9,4
1978	20,9	10,2
1979	22,0	10,9
1980	25,2	11,4

WORKSHEET XVIII: INDICES OF VOLUME OF RAW MATERIALS INPUTS: SOUTH AFRICAN COAL MINING INDUSTRY: 1950-80

YEAR	Bolts, Nuts, Rivets and Washers	Explosives	Detonators	Meat	Other Foodstuffs	Fuel and Power Oil	Lubricating Oils and Greases	Electricity	Spares and Repairs	Remainder of Raw Materials
1950	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
1951	96,2	101,9	114,8	101,5	102,3	100,0	101,4	110,7	100,0	105,9
1952	92,3	122,1	118,5	103,9	98,4	100,0	98,6	117,6	116,7	105,9
1953	100,0	116,9	138,9	93,1	96,9	200,0	104,6	126,0	166,7	141,2
1954	100,0	111,7	129,6	99,2	100,4	200,0	107,1	122,1	166,7	105,9
1955	123,1	137,7	150,0	84,3	94,5	200,0	100,7	138,2	166,7	123,5
1956	130,8	144,2	146,3	95,1	114,5	300,0	114,6	145,0	216,7	123,5
1957	123,1	136,4	146,3	96,7	108,6	400,0	108,2	149,6	233,3	147,1
1958	184,6	145,5	153,7	106,4	115,6	400,0	122,5	162,6	233,3	176,5
1959	342,3	149,4	150,0	113,4	120,3	600,0	123,2	174,8	266,7	211,8
1960	465,4	160,4	168,5	116,7	113,8	900,0	134,6	187,8	316,7	211,8
1961	726,9	163,6	175,9	119,5	124,6	1000,0	141,4	200,0	383,3	229,4
1962	561,5	171,4	183,3	131,4	125,0	1300,0	151,8	216,8	400,0	235,3
1963	1396,2	192,2	205,6	146,5	131,3	1800,0	188,6	248,1	483,3	270,6
1964	1515,4	209,1	220,1	137,3	133,2	2300,0	183,2	292,4	500,0	264,7
1965	1419,2	238,3	255,6	131,6	150,8	2200,0	191,1	306,1	600,0	264,7
1966	1280,8	230,5	244,4	128,5	131,3	2500,0	173,6	310,7	583,3	282,4
1967	1273,1	244,2	331,5	123,4	126,2	3500,0	177,9	445,0	666,7	311,8
1968	1592,3	259,1	268,5	120,3	128,1	3000,0	198,2	366,4	800,0	341,2
1969	2350,0	289,0	285,2	120,6	134,8	3300,0	199,3	404,6	916,7	317,6
1970	3265,4	311,0	287,0	118,5	127,0	4300,0	216,1	427,5	950,0	329,4
1971	3184,6	322,7	437,0	124,7	117,2	6400,0	235,7	454,2	1033,3	317,6
1972	1584,6	332,5	314,8	123,9	132,8	6300,0	234,6	485,5	1033,3	288,2
1973	2257,7	364,9	322,2	119,3	138,3	8100,0	252,9	516,0	1150,0	288,2
1974	3180,8	380,5	300,0	130,8	118,8	10900,0	227,9	526,0	1250,0	282,4
1975	4150,0	434,4	338,9	122,6	127,7	12600,0	293,6	590,1	1600,0	358,8
1976	5026,9	450,0	383,3	140,1	139,8	20100,0	370,7	631,3	2300,0	470,6
1977	3238,5	532,5	437,0	145,5	139,5	27600,0	403,2	765,6	2916,7	552,9
1978	4900,0	635,1	481,5	165,6	141,8	30300,0	472,9	850,4	3483,3	600,0
1979	3615,4	627,3	457,4	166,8	150,0	38000,0	697,9	1008,4	3666,7	541,2
1980	4888,5	681,2	559,3	168,4	144,5	38900,0	482,1	1068,7	4200,0	670,6

WORKSHEET XIX: INDEX OF THE VOLUME OF RAW MATERIALS CONSUMED: SOUTH AFRICAN COAL MINING INDUSTRY, 1950-80: 1950=100

YEAR	INDEX
1950	100,0
1951	104,1
1952	107,9
1953	126,3
1954	114,2
1955	122,1
1956	134,6
1957	143,2
1958	159,5
1959	180,2
1960	190,5
1961	209,6
1962	216,6
1963	255,3
1964	261,7
1965	280,8
1966	278,0
1967	313,1
1968	332,5
1969	351,3
1970	369,0
1971	386,7
1972	367,5
1973	393,0
1974	407,0
1975	494,5
1976	639,9
1977	754,6
1978	871,3
1979	927,2
1980	1007,8

REFERENCES

(1) Department of Mines, Annual Report, published annually, see statistics relating to "stores consumed"; Government Printer, Pretoria.

(2) Chamber of Mines of South Africa, Annual Report, published annually, see statistics relating to "Analysis of all stores consumed during the year by Gold and Coal Mines, Members of the Chamber"; Johannesburg.

(3) Department of Mines, Mining Statistics, published annually, see statistics relating to "value of stores consumed"; Government Printer, Pretoria.

(4) Department of Statistics, "Wholesale Price Index (all groups)", now re-named "Production Price Index": see (1) Quarterly Bulletin of Statistics, published quarterly; (2) South African Statistics, published every two years; (3) Union Statistics for Fifty Years, 1910-60, published March 1960. All Government Printer, Pretoria.

(5) see (1) Department of Agricultural Economics and Marketing, Annual Report, published annually, see "Price Index of Farming Requisites", Government Printer, Pretoria; and (2) Division of Agricultural Marketing Research, Abstract of Agricultural Statistics, published annually, see "Price Indexes of Farming Requisites", issued directly by the Division.

(6) Department of Statistics, "Index of Farming Requisites": see (1) Quarterly Bulletin of Statistics, op.cit.; (2) South African Statistics, op.cit.; (3) Union Statistics for Fifty Years, 1910-60, op.cit.

CHAPTER TEN

THE CALCULATION OF TOTAL FACTOR PRODUCTIVITY IN THE SOUTH AFRICAN COAL MINING INDUSTRY, 1950-80

This chapter utilises the data developed in chapter 9 in order to calculate total factor productivity in the South African coal mining industry over the study period 1950 to 1980 by employing the principles and methods described in chapters 7 and 8. The data necessary to facilitate the required calculations is presented in table 10.1. Indices for output, labour, capital, and raw materials are reproduced from the relevant sections of chapter 9 for the period 1950 to 1980, each of them employing 1950 as the base year.

Input Weighting Scheme

In order that the three separate inputs can be combined into a single input conglomerate (total factor input), a scheme must be devised to weight each of them according to their relative importance. Factor shares are calculated according to the ratio of the total value of each input to the total value of output in some chosen base year. The data necessary to calculate the respective input weights is presented in table 10.2.

Statistics for the coal mining industry relating to the total value of output and the total value of salaries and wages for all employees are readily available from Department of Mines' sources (as shown in footnote 1 to table 10.2) which enable labour's share to be simply calculated for each year during the study period. Likewise, the share of raw materials is obtained as the ratio of the total value of raw materials (reproduced from chapter 9) to the total value of output. Capital's share is obtained as a residual, namely, as the difference between unity and the sum of the shares of labour and raw materials for each year. Over the study period labour's share varies between 0,31 and 0,48 (averaging 0,39), raw materials' share varies between 0,17 and 0,33 (averaging 0,24), and capital's share varies between 0,19 and 0,51 (averaging 0,37).

TABLE 10.1 OUTPUT AND INPUT INDICES EMPLOYED IN TOTAL FACTOR PRODUCTIVITY: 1950 - 80

1950 = 100

Year	Output	Labour	Capital	Raw Materials
1950	100,0	100,0	100,0	100,0
1951	100,4	100,0	101,2	104,1
1952	105,4	103,8	102,8	107,9
1953	107,4	102,2	105,5	126,3
1954	108,6	103,1	107,7	114,2
1955	117,1	108,4	107,5	122,1
1956	125,3	108,9	109,7	134,6
1957	131,1	113,9	112,7	143,2
1958	140,9	120,1	116,6	159,5
1959	138,5	122,3	119,2	180,2
1960	148,2	121,0	122,2	190,5
1961	157,6	128,3	128,2	209,6
1962	159,5	131,6	132,1	216,6
1963	163,0	132,8	137,2	255,3
1964	171,6	139,4	147,2	261,7
1965	185,2	147,6	156,2	280,8
1966	182,5	150,0	163,0	278,0
1967	187,9	143,1	171,6	313,1
1968	196,9	144,3	179,4	332,5
1969	199,2	138,9	188,4	351,3
1970	206,3	136,3	201,0	369,0
1971	221,8	139,8	208,8	386,7
1972	221,8	138,1	215,2	367,5
1973	239,3	133,8	219,2	393,0
1974	251,4	135,0	231,2	407,0
1975	268,9	140,1	261,1	494,5
1976	294,6	153,1	288,0	639,9
1977	330,7	167,9	339,3	754,6
1978	333,5	169,3	370,4	871,3
1979	366,5	167,3	395,7	927,2
1980	406,6	165,5	436,3	1007,8

Source: All figures reproduced from chapter 9.

TABLE 10.2 CALCULATION OF WEIGHTING SYSTEM EMPLOYED IN TOTAL FACTOR PRODUCTIVITY:

Year	Total Value of Output: whole Industry.[1] R Millions	Total Salaries & Wages: All Employees.[1] R Millions	Labour Weight	Total Value of Raw Materials.[2] R Millions	Raw Materials' Weight	Capital Weight
1950	29,6	9,5	0,319	5,0	0,169	0,512
1951	27,1	9,9	0,365	5,8	0,214	0,421
1952	29,3	10,8	0,368	7,2	0,246	0,386
1953	32,9	11,3	0,342	8,2	0,249	0,409
1954	32,2	12,7	0,393	7,5	0,233	0,374
1955	34,7	15,8	0,457	8,2	0,236	0,307
1956	41,5	16,7	0,401	9,1	0,219	0,380
1957	43,3	18,1	0,417	10,8	0,249	0,334
1958	47,2	22,7	0,480	12,2	0,258	0,262
1959	49,4	20,2	0,409	14,8	0,299	0,292
1960	55,1	21,4	0,388	14,6	0,265	0,347
1961	59,6	23,2	0,390	17,6	0,295	0,315
1962	65,1	24,7	0,379	18,8	0,289	0,332
1963	67,7	26,9	0,397	18,9	0,279	0,324
1964	72,2	31,8	0,441	19,6	0,271	0,288
1965	81,4	36,7	0,451	21,9	0,269	0,280
1966	81,5	38,5	0,473	25,3	0,311	0,216
1967	86,9	41,7	0,480	28,7	0,330	0,190
1968	96,9	44,5	0,459	32,2	0,332	0,209
1969	106,3	45,1	0,424	29,9	0,281	0,295
1970	109,9	48,8	0,444	33,3	0,303	0,253
1971	119,4	52,2	0,437	34,8	0,291	0,272
1972	126,8	55,2	0,435	35,1	0,277	0,288
1973	152,1	66,7	0,439	42,5	0,279	0,282
1974	200,0	89,3	0,447	53,6	0,268	0,285
1975	316,1	128,7	0,407	77,8	0,246	0,347
1976	517,8	168,2	0,325	116,8	0,226	0,449
1977	755,4	231,1	0,306	159,3	0,211	0,483
1978	874,4	348,4	0,398	219,0	0,250	0,352
1979	1097,4	433,8	0,395	250,8	0,229	0,376
1980	1404,0	558,8	0,398	310,5	0,221	0,381

Note: all figures for 1978-80 exclude Duvha, Rietspruit and Grootegeluk collieries.

1. Source: Department of Mines, Annual Reports, & Mining Statistics, successive years, Government Printer, Pretoria.

2. Source: Reproduced from chapter 9.

Calculation of Total Factor Input and Productivity

The information jointly contained within tables 10.1 and 10.2 is sufficient to calculate total factor input and productivity. In the first instance productivity will be measured according to the three major methods described initially in chapter 7, namely (i) Kendrick, (ii) Abramovitz-Domar, and (iii) Solow.

(i) Kendrick Method

Kendrick calculated total factor productivity as the ratio of the weighted sum of real inputs (total factor input) to real output. This suggests that the final outcome crucially depends upon the choice of the weights when calculations are performed over an extended time-series. It has been seen that Kendrick periodically changed his weights from one sub-period to another in order to bring them up to date through the chronological progression. Other weighting schemes, however, suggest themselves, and for the purposes of this study three such schemes are attempted in the calculation of total factor input, namely, (a) fixed weights employed throughout, centred on the base year of 1950; (b) weights brought up to date every five years through the chronological progression and based successively on 1950, 1955, 1960, 1965, 1970, and 1975; (c) weights brought up to date annually.

Total factor input calculated according to each of these three weighting schemes is presented in table 10.3. Under scheme (a) fixed weights of labour 0,319, capital 0,512, and raw materials 0,169 are used throughout. Accordingly, all indices are based on 1950 and the composite-input index is progressively constructed on this basis. However, under scheme (b) these weights are changed in 1955 and every five years thereafter. This necessitates a change in the base year and the indices must be re-calculated to reflect the amended base. The new index series must then be "linked in" to the old series to progressively build up the composite-input index. Finally, under scheme (c) the annually-changing weights imply that the base must be updated every year and the linking-in procedure performed annually. As a result each factor-input index number represents the percentage change from the previous year's magnitude.

TABLE 10.3 KENDRICK-RATIO METHOD: TOTAL FACTOR INPUT AND PRODUCTIVITY: 1950 - 80

Year	Total Factor Input 1950 Weights	Total Factor Input 5-yearly Moving Weights	Total Factor Input Annually-Moving Weights	Total Factor Productivity 1950 Weights	Total Factor Productivity 5-yearly Moving Weights	Total Factor Productivity Annually-Moving Weights
			1950=100			
1950	100,0	100,0	100,0	100,0	100,0	100,0
1951	101,3	101,3	101,3	99,1	99,1	99,1
1952	103,9	103,9	104,1	101,4	101,4	101,2
1953	107,9	107,9	108,9	99,5	99,5	98,6
1954	107,3	107,3	107,6	101,2	101,2	100,9
1955	110,2	110,2	111,5	106,3	106,3	105,0
1956	113,6	113,8	115,2	110,3	110,1	108,8
1957	118,2	118,9	120,2	110,9	110,3	109,1
1958	125,0	126,5	127,8	112,7	111,4	110,3
1959	130,5	132,7	133,9	106,1	104,4	103,4
1960	133,4	135,2	136,6	111,1	109,6	108,5
1961	141,9	144,3	145,8	111,1	109,2	108,1
1962	146,2	148,4	150,0	109,1	107,5	106,3
1963	155,7	158,3	160,2	104,7	103,0	101,7
1964	164,1	166,2	168,2	104,6	103,2	102,0
1965	174,6	176,7	178,8	106,1	104,8	103,6
1966	178,4	179,7	181,8	102,3	101,6	100,4
1967	186,4	184,7	187,1	100,8	101,7	100,4
1968	194,1	191,0	193,3	101,4	103,1	101,9
1969	200,2	194,2	195,6	99,5	102,6	101,8
1970	208,8	199,7	200,7	98,8	103,3	102,8
1971	216,9	206,9	207,9	102,3	107,2	106,7
1972	216,4	204,3	205,6	102,5	108,6	107,9
1973	221,3	206,5	207,9	108,1	115,9	115,1
1974	230,3	212,7	213,9	109,2	118,2	117,5
1975	262,0	237,8	237,6	102,6	113,1	113,2
1976	304,4	272,5	272,3	96,8	108,1	108,2
1977	354,8	312,5	313,7	93,2	105,8	105,4
1978	390,9	337,4	338,5	85,3	98,8	98,5
1979	412,7	350,3	350,3	88,8	104,6	104,6
1980	446,5	371,4	369,2	91,1	109,5	110,1

Total factor productivity is also depicted in table 10.3, and is obtained by dividing total factor input as calculated under schemes (a), (b), and (c), into the real-output series in table 10.1.

(ii) Abramovitz-Domar Method

Total factor productivity calculated according to the Abramovitz-Domar Method is depicted in table 10.4. Each of the annual index numbers for output, labour, capital, and raw materials represents the percentage change from the previous year's magnitude. The composite-input index for each year is obtained by base weighting the labour, capital, and raw materials' indices, that is, by the weights of the previous year. This "index of total input of resources" when divided into the output relative for the same year creates the so-called "Abramovitz Residual" which must be linked into the total-factor-productivity index annually in order to build up a progressive series.

(iii) Solow Method

Total factor productivity calculated according to the Solow Method is depicted in table 10.5. Output per man in metric tonnes is simply calculated from the information contained in chapter 9, and the annual percentage change in this series is shown alongside. Annual percentage changes for labour, capital, and raw materials are also reproduced from table 10.4. The capital and raw materials' series are aggregated into a combined index by employing the weights of the previous year and dividing by the sum of these weights. This combined index of inputs is converted to a "per-man" basis by dividing by the labour-change index. The difference from 100 is then weighted by the sum of the previous year's capital and raw materials' weights as already calculated. When this series is divided into the annual change in output per man the resultant residual is linked into the total-factor-productivity index annually in order to build up a progressive series.

Graphical Representation of Total Factor Productivity

The five total-factor-productivity series can now be graphed in order to obtain a better representation of relative movements. However, as analysed in chapter 7, the Kendrick Method with annually-moving weights, the Abramovitz-Domar Method, and the Solow Method are all equivalent and result in identical series. Correspondingly, only three series are depicted in graph 10.1.

TABLE 10.4 ABRAMOVITZ-DOMAR METHOD : CALCULATION OF TOTAL FACTOR PRODUCTIVITY: 1950 - 80

Year	Output	Labour	Capital	Raw Materials	Input	TFP
1950	-	-	-	-	-	100,0
1951	100,4	100,0	101,2	104,1	101,3	99,1
1952	105,0	103,8	101,6	103,7	102,8	101,2
1953	101,9	98,5	102,6	117,1	104,7	98,6
1954	101,1	100,9	102,1	90,4	98,8	100,9
1955	107,8	105,1	99,8	106,9	103,5	105,0
1956	107,0	100,5	102,0	110,2	103,2	108,8
1957	104,6	104,6	102,7	106,4	104,3	109,1
1958	107,5	105,4	103,5	111,4	106,3	110,3
1959	98,3	101,8	102,2	113,0	104,8	103,4
1960	107,0	98,9	102,5	105,7	102,0	108,5
1961	106,3	106,0	104,9	110,0	106,7	108,1
1962	101,2	102,6	103,0	103,3	102,9	106,3
1963	102,2	100,9	103,9	117,9	106,8	101,7
1964	105,3	105,0	107,3	102,5	105,0	102,0
1965	107,9	105,9	106,1	107,3	106,3	103,6
1966	98,5	101,6	104,4	99,0	101,7	100,4
1967	103,0	95,4	105,3	112,6	102,9	100,4
1968	104,8	100,8	104,5	106,2	103,3	101,9
1969	101,2	96,3	105,0	105,7	101,3	101,8
1970	103,6	98,1	106,7	105,0	102,6	102,8
1971	107,5	102,6	103,9	104,8	103,6	106,7
1972	100,0	98,8	103,1	95,0	98,9	107,9
1973	107,9	96,9	101,9	106,9	101,1	115,1
1974	105,1	100,9	105,5	103,6	103,0	117,5
1975	107,0	103,8	112,9	121,5	111,1	113,2
1976	109,6	109,3	110,3	129,4	114,6	108,2
1977	112,3	109,7	117,8	117,9	115,2	105,4
1978	100,8	100,8	109,2	115,5	108,0	98,5
1979	109,9	98,8	106,8	106,4	103,5	104,6
1980	110,9	98,9	110,3	108,7	105,4	110,1

TABLE 10.5 SOLOW METHOD : CALCULATION OF TOTAL FACTOR PRODUCTIVITY : 1950 - 80

Year	Output Per Man (in Metric tonnes)	Annual Change	Labour: Annual Change	Capital: Annual Change	Raw Materials: Annual Change	Combined Weighted Annual Change	Combined Input: Per Man	Weighted	Residual	TFP
1950	469,0	-	-	-	-	-	-	-	-	100,0
1951	470,8	100,4	100,0	101,2	104,1	101,9	101,9	101,3	99,1	99,1
1952	476,3	101,2	103,8	101,6	103,7	102,3	98,6	99,1	102,1	101,2
1953	492,9	103,5	98,5	102,6	117,1	108,2	109,8	106,2	97,5	98,6
1954	493,8	100,2	100,9	102,1	90,4	97,7	96,8	97,9	102,3	100,9
1955	506,7	102,6	105,1	99,8	106,9	102,5	97,5	98,5	104,1	105,0
1956	539,4	106,5	100,5	102,0	110,2	105,6	105,1	102,8	103,6	108,8
1957	540,1	100,1	104,6	102,7	106,4	104,1	99,5	99,8	100,3	109,1
1958	550,2	101,9	105,4	103,5	111,4	106,9	101,4	100,8	101,1	110,3
1959	531,3	96,6	101,8	102,2	113,0	107,6	105,7	103,0	93,8	103,4
1960	574,7	108,2	98,9	102,5	105,7	104,1	105,3	103,1	104,9	108,5
1961	576,1	100,2	106,0	104,9	110,0	107,1	101,0	100,6	99,6	108,1
1962	568,7	98,7	102,6	103,0	103,3	103,1	100,5	100,3	98,4	106,3
1963	575,5	101,2	100,9	103,9	117,9	110,4	109,4	105,8	95,7	101,7
1964	577,2	100,3	105,0	107,3	102,5	105,1	100,1	100,1	100,2	102,0
1965	588,4	101,9	105,9	106,1	107,3	106,7	100,8	100,4	101,5	103,6
1966	570,6	97,0	101,6	104,4	99,0	101,8	100,2	100,1	96,9	100,4
1967	616,1	108,0	95,4	105,3	112,6	109,6	114,9	108,0	100,0	100,4
1968	639,7	103,8	100,8	104,5	106,2	105,6	104,8	102,3	101,5	101,9
1969	672,8	105,2	96,3	105,0	105,7	105,5	109,6	105,3	99,9	101,8
1970	710,8	105,6	98,1	106,7	105,0	105,9	108,0	104,6	101,0	102,8
1971	744,1	104,7	102,6	103,9	104,8	104,4	101,8	101,0	103,8	106,7
1972	753,0	101,2	98,8	103,1	95,0	98,9	100,1	100,1	101,1	107,9
1973	839,0	111,4	96,9	101,9	106,9	104,4	107,7	104,4	106,7	115,1
1974	873,0	104,1	100,9	105,5	103,6	104,6	103,7	102,1	102,1	117,5
1975	899,7	103,1	103,8	112,9	121,5	117,1	112,8	107,1	96,3	113,2
1976	902,3	100,3	109,3	110,3	129,4	118,2	108,1	104,8	95,6	108,2
1977	923,9	102,4	109,7	117,8	117,9	117,8	107,4	105,0	97,4	105,4
1978	923,5	100,0	100,8	109,2	115,5	111,1	110,2	107,1	93,4	98,5
1979	1027,3	111,2	98,8	106,8	106,4	106,6	107,9	104,8	106,2	104,6
1980	1152,1	112,1	98,9	110,3	108,7	109,7	110,9	106,6	105,3	110,1

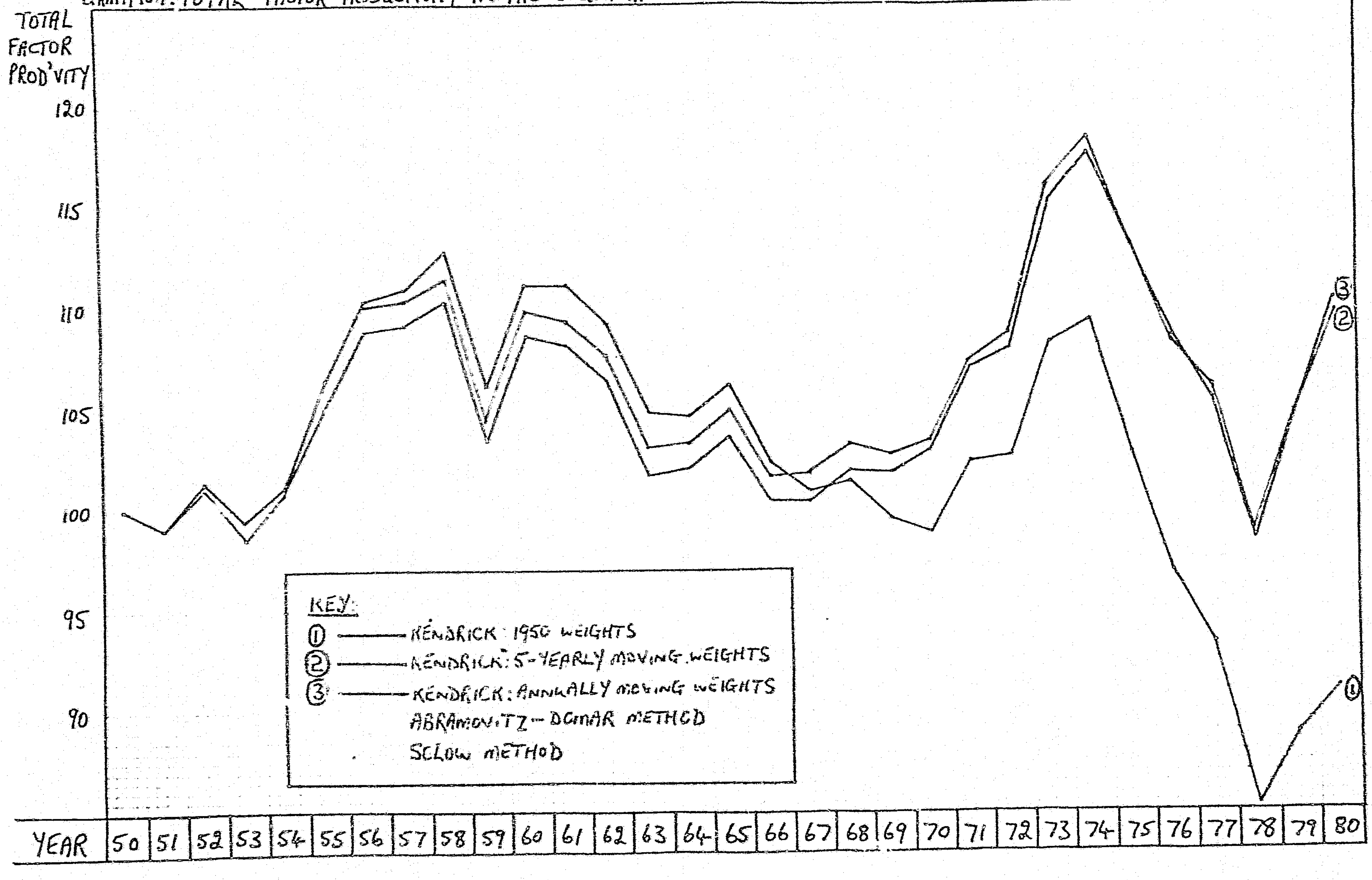
The Use of Value-Added

It was considered a useful exercise to repeat the above analysis with the use of value-added rather than gross output, even though it was shown in chapter 9 that this biases the findings. As it transpired, however, this exercise was found to have few significant effects on the total-factor-productivity series, and, correspondingly, the conclusions are merely reported briefly here with details of data and calculations being omitted. It was observed that the years of peaks and troughs and downward and upward movements in the productivity series correspond with those depicted in graph 10.1. Not surprisingly there are minor differences in the magnitude of the values in the respective series. This stems from the finding that the use of value-added exaggerates the swings so that the troughs fall lower and the peaks rise higher. This would be expected from the discussion in chapter 9.

The Use of Lagged Capital

A case may be made out for the use of lagged capital input in the calculation of total factor productivity in view of the fact that major items of capital expenditure take time to be commissioned and installed and before they commence contributing meaningfully to current output. However, too much should not be made of this argument since the capital figure for any one year represents the aggregate stock accumulated over many previous years. Only the most recent items of expenditure in this total could be argued not to be yet in a position where they are meaningfully contributing to production, and they comprise only a small proportion of the total stock figure. Nevertheless, the exercise was performed of examining the impact on the productivity series of lagging the capital figure by one year. The effect was to shift each of the series upwards by a marginal amount. This made the productivity values more favourable but the shift was so negligible so as not to alter the overall conclusions. Only in the latter years of the 1970's when increasingly large capital expenditures were being incurred did the gap widen to a slightly larger extent.

GRAPH 10.1: TOTAL FACTOR PRODUCTIVITY IN THE SOUTH AFRICAN COAL MINING INDUSTRY: 1950-80. 1950=100



Production Function Approach and Returns to Scale

If series 1 on graph 10.1 is ignored, the other four series are remarkably similar and show that over the study period 1950-80 there has occurred a very small trend rise in total factor productivity at an average rate of 0,3 per cent per annum. A good deal of confidence can be placed in this conclusion. In view of the fact that it is the common result obtained not only from annually-chained indices but also from an index chained in benchmark years there is reason to believe that any substantial errors arising from index-number bias can be discounted. All weighting has been performed on a Laspeyres basis, but re-calculation on a Paasche basis did not reveal significant changes.

However, one potentially serious source of concern still remains. The Kendrick, Abramovitz-Domar, and Solow productivity approaches all operate on the implicit assumption that there are no economies or diseconomies of scale in the industry. The implication is that, except for productivity changes, output changes in the same proportion as inputs. Any deviation from this proportionality is considered productivity change. However, if the industry has experienced any economies or diseconomies of scale, the resultant productivity measure will be biased. Although the measure is a valid representation of output per unit of input it can no longer be considered as an estimate of shifts in the production function.

This section, therefore, is an attempt to evaluate the magnitude of (dis)economies of scale in the coal mining industry over the study period. The most common method is to fit a production function to the data with an added time trend to account for shifts in the function. Consequently, an unconstrained Cobb-Douglas function was fitted to the data in table 10.1 of the form,

$$X = AL^{\gamma}K^{\sigma}R^{r}e^{\delta T}$$

where X, L, K, and R represent gross output, labour, capital, and raw materials; γ, σ, and r represent the elasticity of output with respect to labour, capital, and raw materials respectively; A is the output scaling co-efficient; and $e^{\delta T}$ is an added exponential time trend to capture the residual growth in efficiency, with T expressed in years. The objective is to discover whether $\gamma + \sigma + r = 1$ and if not the effect which this has on the average residual trend of productivity depicted by the co-efficient on the time trend δ.

The co-efficients are determined by running an ordinary-least-squares regression on the linear-in-logarithms transformation of the Cobb-Douglas function,

$$\log X = \log A + \gamma \log L + \sigma \log K + r \log R + \delta T .$$

The results obtained were as follows, with the standard error of each co-efficient being shown in brackets,

$$\underset{(0{,}18)}{\gamma = 0{,}14} \quad \underset{(0{,}12)}{\sigma = 0{,}25} \quad \underset{(0{,}13)}{r = 0{,}19} \quad \underset{(0{,}002)}{\delta = 0{,}0067} \ : \ R^2 = 0{,}993 .$$

The effect of lagging the capital-input variable by one period resulted in the following estimates,

$$\underset{(0{,}18)}{\gamma = 0{,}09} \quad \underset{(0{,}11)}{\sigma = 0{,}19} \quad \underset{(0{,}12)}{r = 0{,}26} \quad \underset{(0{,}002)}{\delta = 0{,}0063} \ : \ R^2 = 0{,}993 .$$

The sums of the co-efficients in the above two regressions are 0,58 and 0,54 respectively, indicating a strong presence of diseconomies of scale. The existence of decreasing returns to scale has detracted from the magnitude of the productivity residual in the Kendrick, Abramovitz-Domar, and Solow approaches which assume constant returns to scale and resulted in the downward-biased estimate of 0,3 per cent per annum. Correction for this bias would give an average productivity trend in excess of 0,6 per cent per annum as shown by the values of δ in the above two regressions.

However, these results must be viewed with a fair degree of circumspection. Theoretical, philosophical, statistical, and econometric problems abound. The theoretical foundations of the aggregate production function give one grounds for doubting whether the concept is useful at all; the appropriateness of the Cobb-Douglas function as a description of the production process can be questioned; and, finally, a gamut of econometric problems are introduced associated with attempting to obtain time-series estimates of co-efficients in an aggregate Cobb-Douglas function. The results of econometric studies should always, as a general rule, be received with a good deal of scepticism. The fact that a function seems to fit the data very well is no guarantee that the model is a realistic one. These problems have previously been raised in chapters 7 and 8 and there is no need to discuss them in detail here. However, they must be borne in mind when interpreting the regression results above.

The multiple correlation co-efficient of 0,993 for both regressions indicates an extremely good fit. In addition, the estimate of the productivity trend co-efficient δ is significant at the 95-per-cent confidence level in both regressions. However, the estimates of the input co-efficients show less significance. At the 95-per-cent level of confidence only the capital-co-efficient estimate is significant in the first regression, whilst only the raw materials'-co-efficient estimate is significant in the lagged regression. Undoubtedly, multicollinearity is a major problem. All the variables display strong upward trends and are highly correlated with the result that it is difficult to disentangle the effects of the separate variables. Because of this one can have little faith in the co-efficients actually allocated to individual inputs, including the co-efficient on the trend term used as a measure of the rate of growth of total factor productivity. Although the allocation of the co-efficient estimates between the different inputs can be regarded with a good deal of scepticism, the value of the sum of the co-efficients is less questionable, leading to the conclusion that decreasing returns to scale are undoubtedly evident.

The problems posed by multicollinearity become more evident when value-added rather than gross output is employed as the dependent variable. Two regressions were run, one using current capital input and the other using lagged capital input. In both cases the input co-efficients collapsed, becoming totally insignificant and adopting the wrong sign. Accordingly, all the significance was thrown onto the intercept and trend terms. These results provide an example of the near impossibility of untangling the separate effects of highly-correlated independent variables and the unreliable co-efficient estimates which are subsequently allocated.

It will be recalled from the discussion in chapter 8 that the procedure adopted in this section amounts to a Walters'-type amendment of a model constrained to constant returns to scale in order to account for (dis)economies of scale. The argument was advanced at that stage that such an amendment overcompensates, and that the ideal situation corresponds to a mid-way position between the extremes of a function constrained to constant returns on the one hand and the Walters'-type approach on the other. Bearing this argument in mind, together with our scepticism concerning the accuracy of the trend-co-efficient estimate of 0,67 per cent per annum for reasons advanced above, the only valid conclusion which can be reached in this section is that there exists clear evidence of decreasing returns to scale which imply a scaling-up of the previous productivity-trend estimate of 0,3 per cent per annum but not necessarily to the level of 0,67 per cent per annum which is probably an over-estimate.

Finally, the use of an exponential trend to capture the residual-productivity factor can be questioned. Examination of graph 10.1 clearly reveals that the movement of the total-factor-productivity series cannot adequately be captured by the assumption of a constant annual percentage improvement, and, consequently, the bias in the estimate of the trend co-efficient δ must be admitted.

Weighting System Employing Production Function Co-efficients

The suggestion was made in chapter 8 when reviewing the work of Maddala that rather than using observed factor shares as weights a more-appropriate approach would be to employ the factor shares obtained by fitting a Cobb-Douglas production function to the data, that is, the estimated input co-efficients γ, σ and r. However, in view of the severe multicollinearity in the data, which makes a mockery of the accuracy of the estimated co-efficients, such an exercise would be meaningless and misleading and was not attempted.

Elasticity of Substitution

The assumption of a unit elasticity of substitution is implicit in the use of a Cobb-Douglas production function. An attempt to test the accuracy of this assumption can be made by employing the SMAC formulation of the CES function,

$$X = \kappa e^{\lambda t}[\delta K^{-\rho} + (1-\delta)L^{-\rho}]^{-\frac{1}{\rho}}$$

with the objective of estimating the value of ε (elasticity of substitution) and λ (technological-progress trend).

Following the analysis in chapter 7, three regressions were fitted,

(i) $\log (X/L) = \varepsilon \log \omega$

(ii) $\log (X/L) = b_2 \log \omega + b_1 t$

(iii) $\log (X/L) = \pi_1 \log \omega + \pi_2 t + \pi_3 \log(X/L)_{t-1}$

where X/L is value-added per man, ω is the real-wage-rate series and t is a time trend expressed in years.

The following co-efficients were estimated by means of ordinary least squares (with standard errors in brackets),

(i) $\varepsilon = 0{,}452$ (0,021) $R^2 = 0{,}938$

(ii) $b_2 = 0{,}256$ (0,049) $b_1 = 0{,}005$ (0,001) $R^2 = 0{,}963$

(iii) $\pi_1 = 0{,}08$ (0,044) $\pi_2 = 0{,}001$ (0,001) $\pi_3 = 0{,}79$ (0,13) $R^2 = 0{,}984$

and from the relationships shown in chapter 7 it is possible to calculate the values of ε and λ in each case, namely,

(i) $\varepsilon = 0,452$

(ii) $\varepsilon = 0,256$ $\lambda = 0,0067$

(iii) $\varepsilon = 0,381$ $\lambda = 0,0077$.

These results indicate that the value of the elasticity of substitution lies between zero and unity with a residual-productivity trend of between 0,67 and 0,77 per cent per annum. Once again these estimates should only be regarded as a guide in view of the problems already mentioned. Multicollinearity is particularly a problem in regression (iii) (the McKinnon formulation). The co-efficient estimates for π_1 and π_2 are not significant at the 95-per-cent confidence level in the presence of π_3 the lagged series of the dependent variable. Since one has little confidence in the accuracy of these reported estimates, consequently the calculated value of 0,77 per cent per annum for the residual trend is subject to a great deal of scepticism since the value of λ is derived from the relative values of

π_1, π_2, and π_3.

Conclusion on the Production Function Approach

Stemming from the above analysis, three main conclusions suggest themselves;

(a) there is evidence of decreasing returns to scale,

(b) the value of the elasticity of substitution appears to lie between zero and unity,

(c) productivity growth has proceeded at an average rate of approximately 0,67 per cent per annum (rising to 0,77 per cent per annum in McKinnon's lagged-adjustment formulation).

One is tempted, however, whilst not rejecting these conclusions outright, to place them in their correct perspective and treat them with some degree of circumspection. The estimate of the average rate of productivity growth falls especially into this category. There is no need to repeat the myriad problems associated with time-series econometric estimation employing an explicitly-defined production function, but, in particular, the problems associated with multicollinear independent variables together with the obvious inadequacy of employing an added exponential trend term to capture total factor productivity, means that one can have only limited confidence in the estimates allocated to the input parameter co-efficients and in the estimate of the trend co-efficient.

In view of this reasoning it would appear that a much more accurate interpretation of the movement of total factor productivity is provided by the ratio method of output-per-unit-of-input as devised by Kendrick, Abramovitz-Domar, and Solow and shown as series 2 and 3 in graph 10.1.

Analysis of Total Factor Productivity

An examination of graph 10.1 reveals that over the study period productivity was approximately 10 per cent higher in 1980 than in 1950, reflecting an almost negligable average rate of growth of 0,3 per cent per annum. Such an interpretation is misleading, however, for no such steady growth is revealed. Rather the respective series go through several sections of varying up and down productivity trends, and, for example, only two years before the end of the study period in 1978, productivity stood at a level slightly lower than it had been in 1950. The only valid conclusion that can be reached is that the study period has been characterised by a series of varying productivity trends and by 1980 stood at a level which suggested that there was no significant evidence that coal was being mined more productively in that year than in 1950.

Five distinct sub-periods can be demarcated between 1950 and 1980, as below :

1950-1958 : An eight-year period (peaking in 1958) of improving productivity at an average trend rate of 1,3 per cent per annum, 1959-1967 : A nine-year period (troughing in 1967) of declining productivity at an average trend rate of - 1,0 per cent per annum,

1968-1974 : A seven-year period (peaking in 1974) of improving productivity at an average trend rate of 2,2 per cent per annum,

1975-1978 : A four-year period (troughing in 1978) of declining productivity at an average trend rate of -4,1 per cent per annum,

1979-1980 : A two-year period of improving productivity at an average trend rate of 5,3 per cent per annum.

The study period has, therefore, experienced two complete cycles of peaks and troughs, with the swing becoming more pronounced in the second cycle, that is, the peak rose higher and the trough fell lower. In view of these swings it would be a naive conclusion merely to state that productivity was no higher in the late 1970's than in 1950. What is required is an explanation of the reasons for the swings.

Of particular interest are the reasons for the setbacks in productivity experienced during the 1959-67 and 1975-78 periods. Table 10.6 below shows the average annual percentage change in output (from column 1 in table 10.1) and total factor input employing Kendrick annually-moving weights (column 3 in table 10.3) as well as the average annual growth of total factor productivity during each of the five demarcated sub-periods.

TABLE 10.6 AVERAGE ANNUAL GROWTH IN PRODUCTIVITY VARIABLES

Period	Output	Total Factor Input	Total Factor Productivity
1950-1958	4,3	3,1	1,3
*1959-1967	3,2	4,3	-1,0
1968-1974	4,2	2,0	2,2
*1975-1978	7,4	12,1	-4,1
1979-1980	10,4	4,5	5,3

The negative productivity trends during the two "offending" sub-periods (marked with an asterisk) have clearly been caused by an inability to keep input increases under control in relation to the growth of output. Despite a slower rate of increase of output between 1959 and 1967 (for reasons explained in chapter 2) when compared with the 1950-58 sub-period, nevertheless, there was a rise in the rate of increase of input utilisation. This rise was reversed in the following 1968-74 sub-period despite a recovery in the growth of output. Input utilisation again went out of control during the 1975-78 sub-period, but, as previously, was successfully reversed after 1978 despite a large increase in output growth.

Obviously an explanation is required for the behaviour of input utilisation. Greater insight would be obtained if the input variable was decomposed into its constituent parts. In table 10.7 below total factor input is segmented to show the average annual percentage changes in labour, capital, and raw materials separately during each of the five demarcated sub-periods. For purposes of comparison the figures for the growth of output and total factor productivity are reproduced from table 10.6.

TABLE 10.7 AVERAGE ANNUAL GROWTH IN PRODUCTIVITY VARIABLES

PERIOD	OUTPUT	LABOUR	CAPITAL	RAW MATERIALS	TOTAL FACTOR PRODUCTIVITY
1950-1958	4,3	2,3	2,0	6,0	1,3
*1959-1967	3,2	2,0	4,3	7,7	-1,0
1968-1974	4,2	-0,8	4,2	3,9	2,2
*1975-1978	7,4	5,8	12,6	21,0	-4,1
1979-1980	10,4	-1,2	8,5	7,5	5,3

The negative productivity trends during the two "offending" sub-periods have clearly been caused by an inability to keep the increase in capital and raw materials inputs under control. Both rose significantly faster than the growth of output during these periods, especially in the case of raw materials. In the other three periods the increase in capital and raw materials inputs was far more moderate and it was the bringing under control of these inputs in relation to the rise in output that resulted in positive total-factor-productivity growth during these periods.

Further analysis of raw materials input is now required in order to identify which components were responsible for the large surge in usage during 1959-67 and 1975-78. Examination of table 9B.1 together with worksheet XVIII in Appendix B of chapter 9 reveals that in view of the weighting structure adopted and the trends displayed by the various categories of items comprising the raw materials input, the three components to concentrate on are spares and repairs, electricity, and the remainder of raw materials. Table 10.8 below shows the average annual percentage change in each of these three items during the five sub-periods under examination.

TABLE 10.8 AVERAGE ANNUAL GROWTH IN MAJOR RAW MATERIALS COMPONENTS

PERIOD	SPARES AND REPAIRS (weight gradually rising from 12 to 43)	REMAINDER OF RAW MATERIALS (weight gradually falling from 36 to 23)	ELECTRICITY (weight between 8 and 10)
1950-1958	11,1	7,4	6,3
*1959-1967	12,4	6,5	11,8
1968-1974	9,4	-1,5	2,4
*1975-1978	29,2	20,7	12,6
1979-1980	9,8	5,7	12,1

These figures reveal the same pattern, namely that there was an inability to control the above inputs during the "offending" two sub-periods, in contrast to the successful control exercised during the other three sub-periods. In examining the magnitude of the above figures in association with their allocated weights it appears that emphasis should be laid on the item "spares and repairs" which is a dominating influence in the movement of the raw materials input data shown in table 10.6.

In view of these observations it is necessary to undertake a closer examination of the dominant events characterizing each of the demarcated five sub-periods.

Five Sub-Periods of Productivity Growth.

The pinpointing of the high rate of change of the raw materials input during 1959-67 and 1975-78 in table 10.7 and, in particular, the trend rate of spares and repairs during respective sub-periods in table 10.8, strongly suggests that analysis should be concentrated on major changes in mechanisation policies during the study period.

1950-1958 : It was reported in chapter 4 that the complete dominance of hand loading and tramming in South Africa was only disturbed as late as November 1947 with the introduction of the mechanical loader followed approximately one year later by the introduction of shuttle cars in December 1948. These tentative moves in the direction of what is now called conventional LHD (load-haul-dump) methods initiated a flush of enthusiasm during the next three years, so that the Department of Mines was able to state in its Annual Report that by 1951 seven of the 65 producing collieries in the Union were fully mechanised (1). This initial surge was mainly accounted for by new mines commissioned in the wake of the Second World War that had decided to open up on full mechanisation. The Report also added that other older-established mines were "seriously considering" a change-over to mechanical methods of mining. The stage, therefore, seemed set for the widely-based introduction of LHD mechanisation during the 1950's.

In retrospect it can now be noted that this expected development did not materialise. Mechanisation stagnated during the 1950's to such an extent that ten years later in 1961 Fraser reported that there were still only seven fully-mechanised coal mines in the Republic, although a further eight operated mechanised sections combined with hand-got sections (2). It appears obvious, therefore , that the period 1950-58 was not characterized by any significant growth in the percentage of coal obtained by conventional LHD methods, remaining virtually static at between 8 and 10 per cent.

<u>1959-1967 :</u> A serious challenge to the 90-per-cent domination of hand-got mining only began to materialise from the early 1960's. The major characteristic of the period 1959-67 was the significant growth in the adoption of conventional LHD mining. The Chamber of Mines' Annual Report stated in 1965 that "modern mechanised coal mines are now producing a significant proportion of South Africa's supplies" (3). By the end of 1967 between 20 and 25 per cent of the Republic's coal (approximately 11 million tonnes) was produced by conventional LHD methods, as compared with the approximately 3 million tonnes produced by these methods in 1958. Between these dates total coal sales increased by 12 million tonnes, so that approximately 67 per cent of this increase was accounted for by mechanised methods. Much of the growth was provided by collieries "tied" to ESCOM power stations commissioned during this period, such as Usutu and Blinkpan, which were fully mechanised from the outset.

The sub-period 1958-67 could, therefore, be described as the era when LHD mining spread out from a narrow base of a small number of collieries to become fairly well diffused throughout the industry. The general suspicion of mechanised methods which had prevailed throughout the 1950's was gradually broken down. Most colliery management had adopted a "wait-and-see" attitude and were reluctant to abandon the tried-and-tested hand-got method which had served them well for many decades. Particularly by the mid-1960's a new attitude was beginning to prevail. Since this was a period characterised by the introduction of new technology it could be described as a learning period. Both management and workers suffered from unfamiliarity. Mistakes were made. The main concern was to gain experience and to adapt as quickly as possible to the changing situation.

1968-1974 : By the end of 1967 the learning period for LHD mechanisation appears to have been completed. These methods were fully accepted and had been thoroughly tried and tested. During this period colliery management appears to have benefited both from their own acquired experience and the published mistakes of others. LHD mechanisation was extensively installed and utilised far more efficiently than in the years before 1967. By the end of 1974, approximately 60 per cent of all coal produced (or 39 million tonnes) was extracted by mechnical methods, a large increase from the 11 million tonnes mined at the begining of the sub-period. This rapid expansion of LHD mechanisation was at the expense of hand-got extraction whose contribution had fallen to approximately 29 per cent of all coal produced (or 19 million tonnes) by the end of 1974(4).

1975-1978 : LHD extraction methods involving power loaders and shuttle cars were not destined to exceed the level of 60 per cent of all coal produced, achieved in 1974. The major characteristic of the period 1975-78 was the significant growth in the adoption of open-cast mining, longwalling, and the use of continuous miners. Between them these methods accounted for only approximately 11 per cent (or 7 million tonnes) of all coal produced in 1974. Four years later in 1978, however, these methods accounted for 28 per cent (or 24 million tonnes) of all coal produced. The hand-got contribution fell to 15 per cent (13 million tonnes) and the conventional LHD contribution fell slightly to 57 per cent (49 million tonnes).

The sub-period 1975-78 could, therefore, be described as another era characterised by the introduction of new technology when these "other" methods of extraction, particularly continuous miners and open-cast mining, became generally accepted and employed fairly widely throughout the industry. As with the widespread introduction of conventional LHD mining between 1959 and 1967 this could be described as a learning period characterised by unfamiliarity on the parts of both management and workers.

1979-1980 : By the end of 1978 the learning period for these "other" extraction methods appears to have been completed. Increased experience and familiarity has resulted in more efficient utilisation of these mechanical processes.

CONCLUSION

The above discussion gives rise to the firm conclusion that the explanation for the setback in productivity growth experienced over the sub-periods 1959-67 and 1975-78 can be found in the industry's inability to control the extensive increases in the utilisation of spares and repairs inputs. These periods were characterised by the introduction of new technology, in the former case conventional LHD mechanisation and, in the latter case, open-cast mining and continuous miners (and to a lesser extent longwalling). They could, therefore, be described as learning periods. Quite understandably the industry made mistakes during these times, a natural part of the process of gaining experience, learning and adapting. In the search for optimum utilisation incorrect applications are bound to be encountered. Unfamiliarity on the part of both management and operators combined with some degree of sub-efficient machine design resulted in many "teething problems" and extensive breakdowns during these learning periods. Correspondingly, the industry lost control of spares and repairs inputs. It is noticeable that once more familiarity was achieved in the operation of these methods that the increase in spares and repairs utilisation was reduced to more acceptable levels and positive productivity growth was experienced.

Further analysis of these points is reserved for chapter 11.

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CHAPTER ELEVEN
SUMMARY AND CONCLUSIONS

The objective of this thesis has been to measure the contribution made by productivity growth to output changes in the South African coal mining industry during the period 1950-80. Chapters 1 to 5 were devoted to an analysis of those factors which are generally considered to be of primary importance in the determination of productivity levels. It will be recalled that the influence of these factors was found to be varied - some of them undoubtedly sustaining positive productivity growth in the industry during the study period whilst others, without doubt, detracted from this growth.

From the host of issues examined there would be fairly general consensus that the following factors should have contributed in a positive manner to productivity growth over most of the study period;

- favourable natural and geological conditions, combined with the absence of fears of depletion of coal reserves, thus allowing the mining of only "easy" seams by wasteful methods (chapter 1);

- the retention of the mining, preparation and marketing of coal in the hands of private enterprise (chapter 3);

- the gradual adoption of more-sophisticated, capital-intensive methods of extraction (chapter 4).

On the other hand the following factors should have exerted an unfavourable influence;

- negative economic and other extraneous issues such as a low controlled coal price, erratic supplies of railway trucks, and alternating periods of sluggish demand patterns (chapter 2);

- the myriad problems stemming from the employment of a large unskilled, low-paid, unmotivated, unstable black migrant labour force (chapter 5).

Although discussion of these negative and positive factors is an important element in the analysis, the major purpose of this thesis was to quantify their aggregate impact. Correspondingly, this necessitated an examination of the methods that could be employed in the measurement of productivity (chapters 6 to 8), followed by the construction of the necessary variables required in the analysis (chapter 9), and, finally, the calculation of the movement of aggregate productivity in the industry (chapter 10).

Conclusions

Several interesting findings stem from the analysis of chapter 10. However, four major conclusions can be stated below:

(1) The industry has experienced three main extraction technologies during the study period, progressing from the simple techniques of hand-got mining to conventional load-haul-dump methods (LHD), and, finally, to the sophisticated capital-intensive techniques embodied in open-cast mining, longwalling and continuous miners. However, in spite of these significant advances in extraction processes there is no evidence to suggest that, in terms of input foregone per unit of output produced, coal was mined any more productively in the late 1970's as compared with 1950. The 1978 and 1950 productivity levels are virtually identical, and it is only significant growth during 1979 and 1980 which places the latter figure approximately 10 per cent above the 1950 benchmark.

(2) No constant productivity trend has been observed during the study period. Rather five separate trends can be demarcated, generally corresponding to periods of learning and familiarity with the different extraction technologies. These five sub-periods are shown in table 11.1 below.

TABLE 11.1 SUB-PERIODS OF PRODUCTIVITY GROWTH

PERIOD	MAJOR CHARACTERISTICS	PRODUCTIVITY TREND	RATE
1950-58	Familiarity : Hand-got	Up	1,3
1959-67	Learning : Conventional LHD	Down	-1,0
1968-74	Familiarity : Conventional LHD	Up	2,2
1975-78	Learning : Open-cast, Continuous Miners, & Longwall	Down	-4,1
1979-80	Familiarity : Open-cast, Continuous Miners, & Longwall	Up	5,3

(3) Industry management can be faulted for misjudging the effects stemming from the introduction of new technologies. There appeared to be widespread belief that there would be an immediate positive impact on productivity. In fact the opposite occurred as the industry struggled to familiarize itself with the new techniques. The normal increase in capital expenditure during these periods was exacerbated by phenomenal increases in spares and repairs inputs which explains the downturn in productivity. There was a lack of prior realisation of these developments, and, hence, an absence of any kind of co-ordinated planning. As a result the industry struggled to correct itself through mine-to-mine experiments and adaptations, and was generally characterised by crisis management on a trial-and-error basis.

(4) It will be observed from table 11.1 that the second learning period was significantly shorter than the first (four years as compared with nine years) despite the fact that the type of equipment being introduced during this period was far more sophisticated than conventional LHD machinery. Obviously, this was a case of workers, management, and manufacturers "learning more quickly" as they benefited from the experience of the past.

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Detailed Summary

Further elaboration of these conclusions is now required. Accordingly, each of the five sub-periods will be analysed in the light of the conclusions presented above.

1950 - 58 : Familiarity, Hand-got

Hand-got mining methods enjoyed a 90-per-cent domination in terms of coal-extraction volumes throughout the 1950's. They represented a technology which had been utilised for decades and was well suited to the non-machine-minded mentality of the large black labour force. Familiarity on the part of both workers and management with the uncomplicated techniques involved was reflected by a steady trend rise in productivity until the year 1959. With output rising at an average annual rate of 4,3 per cent in the face of fairly buoyant demand, total factor input growth was restricted to 3,1 per cent. Increases in productivity would hav een even more impressive but for a growth rate in raw materials of 6,0 per cent per annum, with spares and repairs recording a figure of 11,1 per cent. Much of the maintenance and repair work was devoted to drills and cocopans and most mines operated fairly large workshop areas. The nature of the repairs, however, was generally routine. The simple, rugged equipment in use necessitated only straightforward maintenance work and repairs were uncomplicated (although fairly frequent in view of the large number of cocopans in use and the rough treatment they received).

1959 - 67 : Learning, Conventional LHD

The introduction of conventional LHD equipment ushered in a learning period which lasted until 1967. Productivity growth was negative at an average rate of 1,0 per cent per annum. Output growth slipped to an average annual rate of 3,2 per cent in the face of some stagnant markets experienced during the early and middle 1960's, but in spite of this total factor input grew at the increased annual rate of 4,3 per cent. Not surprisingly, during this technologically-innovative period, capital input grew at the increased rate of 4,3 per cent annually, whilst labour growth declined, but raw materials input showed a rise to 7,7 per cent annually, mainly due to increased growth rates in spares and repairs and electricity, which reached 12,4 and 11,8 per cent respectively.

The decision to introduce the conventional LHD "trackless revolution" into South African collieries on a widespread scale from the late 1950's onwards was generally based on three considerations:

(I) the "troublesomeness" of black labour, particularly increasing shortages of labour and rising (but still relatively low) wage rates and labour-associated costs such as food, hostel accommodation, and so on,

(II) comparative cost and production analyses which showed conventional LHD mechanisation to be more cost and production effective than traditional hand-got mining,

(III) the existence in the Transvaal and Orange Free State of "ideal" geological conditions for mechanisation in the form of shallow, thick, horizontal seams, with wide bords, strong roofs, and generally hard, dry, level floors, comparable in many ways with those prevailing in the United States.

These circumstances led industry management to adopt the standpoint that in view of the similarity in conditions there appeared to be no valid reasons, from the technical viewpoint, why mining layouts and types of machinery corresponding to those utilised in America should not be introduced into South Africa with equal or even greater success (1). Accordingly, machinery designed and manufactured in America was imported into South Africa and put to work underground with no modification.

In retrospect, it now seems clear that this analysis was over-simplistic and ignored several pertinent points. Industry management failed to realise that there were many other relevant issues which should have received consideration. It was this failure which explains the reasons for the checkered success of LHD's introduction, the long learning period endured, and the downward trend of productivity experienced instead of the upward trend which had been widely anticipated. In particular, inadequate consideration was given to the significance of the operating costs of LHD machinery, especially the importance which maintenance, spares and repairs would assume. Such realisations only came to light once the decision to mechanise had been made and a colliery was then committed to that course of action. It is a poor time to realise that serious miscalculations have been made in respect of spares and repairs after the machinery has been introduced underground.

Several factors which were either ignored completely or given inadequate consideration at the time can now be discussed below:

(a) The overseas' manufacturers of trackless coal cutters, power loaders, and shuttle cars were responsible for supplying equipment with design specifications not suited to the type of labour which would operate it in South Africa. The bulk of the machinery was imported from the United States and although the design specifications may have been considered ideal for machine-conscious American labour, they proved deficient when operated by non-machine-conscious black South African labour. Rossocha had realised, and warned, in 1960 that such machinery had been developed to suit conditions where labour was "highly paid, very machine-minded, individualistic, full of enterprising spirit, and a bit resentful of doing heavy monotonous physical work" (2). It can hardly be claimed that these traits were evident amongst black South African labour during the late 1950's and early 1960's. In other words, both geological and labour conditions had to be correct to accommodate the successful introduction of trackless machinery. South African industry management chose to lay stress on the "ideal" geological conditions to the detriment of the far from ideal labour situation, and, correspondingly, were less than successful in transposing unmodified American technology to the local situation.

Black South African labour had been accustomed for many decades to working with simple, robust machinery characteristic of hand-got mining, but a completely different approach was required to successfully operate the relatively more-fragile and sophisticated equipment of LHD mining. Such machinery had not been designed to withstand the "rough" treatment it subsequently received. Consequently, breakdowns proliferated to such an extent that it soon became obvious that the significance of spares, repairs, and maintenance inputs had been under-estimated. Popular abuses of machinery are too numerous to mention in detail, but several common faults (usually discussed informally amongst meetings of mining men rather than being officially recorded) associated with the driving of shuttle cars can be mentioned;

- vehicles driven at unsuitable speeds in relation to varying conditions of load and grade,
- incorrect acceleration producing excessive shock-load on gears and shafts,
- frequent "lugging" or stalling of the engine,
- reversing the vehicle while tramming forward at full speed.

(b) In comparison with traditional hand-got mining one would automatically expect a greater volume (deflated cost) of spares and repairs to be associated with trackless LHD equipment simply because the machinery is more sophisticated and there are "more things" which can potentially go wrong. This applies regardless of the quality of labour which is utilised. The potentiality for breakdown in a system characterised by shovels, cocopans, and steel ropes can hardly be compared with the complexities of a system utilising trackless coal cutters, power loaders, shuttle cars, and continually-extendable conveyor belting.

Collieries habitually experienced two distinct types of system failure, firstly, initial teething problems, and, secondly, on-going breakdowns. In regard to the former, many modifications and adjustments had to be made within a short period of introducing the machinery underground. This could be regarded as a period of experimentation but was, nevertheless, costly in terms of lost production and repair costs. In regard to the latter, mobile equipment suffers from the disadvantage of frequent failure and replacement of certain critical parts. For instance , shuttle cars were subject to serious delays arising from problems associated particularly with trailing cables, and the failure of flight and chain conveyors, tyres, hoses, clutches, gears, and batteries.

In addition, mobile machines such as loaders and shuttle cars in any given size range were (and are) built for maximum capacity within the permissible height in which they are designed to work. The compactness which results from this tends to reduce accessibility for maintenance purposes. This increases both the downtime and the cost for all running repairs and overhauls in comparison with hand-got extraction.

(c) It should not be imagined that it was only black labour which presented problems in the handling and operation of the new LHD machinery. Whilst white artisans who were responsible for servicing and repairing the equipment could hardly be accused of being non-machine-conscious, at the same time, they were not familiar, at least initially, with the type of machinery they were expected to service. Effective maintenance is required to ensure reduced breakdowns, to eliminate failure during a critical stage of the operation. As a result, training of artisans assumed important dimensions to enable proper fault-finding and servicing. In the interim, however, artisan unfamiliarity proved costly in two directions. Firstly, failure to withdraw a machine for maintenance before the injury resulting from the fault assumed serious proportions and damaged expensive parts, for instance, inability to detect and replace a faulty bearing before the casing housing the bearing is also damaged. Secondly, the absence of any methodical maintenance procedure. In the early days servicing schedules were essentially ad hoc and only after slow and costly experience were more-efficient operations devised.

(d) As mentioned earlier, there was an absence of local manufacture of underground mobile machinery which had to be imported from overseas. The South African representatives of these foreign firms found themselves in the position whereby they were not always able to carry a comprehensive stock of spare parts for the wide diversity of machines employed in what was regarded as a relatively minor coalfield by world standards. As a result, the burden was thrown onto individual collieries themselves to carry a larger stock of spares than would normally be deemed necessary, or else to place the responsibility onto their own workshops and engineering resources for fashioning the required parts. Either course of action results in an escalation of maintenance, spares and repairs inputs.

(e) In view of this retrospective importance attached to spares and repairs it is remarkable that these obvious issues were not foreseen in advance by industry management. The comparative analyses that were performed tended to be deficient in various ways. Almost invariably the approach was to compare a typical hand-loading colliery with a trackless mechanised colliery for identical outputs, and analyse either production capabilities, labour requirements, or capital expenditure required to bring the two collieries to production (3). All three approaches completely ignore spares, repairs and maintenance. Other studies which did attempt to take some items of operating expenses into account invariably under-estimated the importance of the role which spares and repairs were destined to play. They either calculated these inputs on the basis of United States' documented evidence (which, as can be seen from the above arguments, cannot be translated into the South African situation) or else failed to directly quantify their importance and merely relegated their significance to a warning note in the main text (4).

1968 - 74 : Familiarity, Conventional LHD

The declining productivity of the 1959 - 67 period was transformed into positive productivity growth over the ensuing years 1968 - 74. This is explained by the fact that the widespread expansion of LHD mining to account for 60 per cent of all coal mined by 1974 predictably not only resulted in an average annual decline in labour employed but saw a fall in the average annual increase in raw material inputs from 7,7 per cent to 3,9 per cent. The three major components of raw materials (spares and repairs, electricity, and the remainder of raw materials) all experienced significant declines in their rates of growth during this period. Undoubtedly the LHD learning period had been completed and the industry had entered an era of familiarity during which it was able to reap the benefits of the mistakes which had been made and the experience which had been gained during the previous nine years.

Three main explanations can be offered. Firstly, both black and white labour had become sufficiently familiar with the LHD machinery as to become proficient in its efficient operation and maintenance. Particularly in the case of black labour, "learning by doing" was a major factor in enhancing machine-consciousness, but the role played by changes in emphasis in training programmes should also be stressed. Such training techniques have already been examined in chapter 5. The view came to be widely expressed in the late 1960's and early 1970's that black labour was performing excellently with mechanised extraction. In the case of white artisans employed on maintenance work, "learning by doing" and specific training programmes on LHD equipment also played their part, but the most significant development was the assuming of responsibility by the coal industry for the indenturing of its own apprentices as fitters, electricians and platers at the Colliery Training College in Witbank. For the first time, therefore, the industry was able to mould its own artisans from first principles to the specific requirements of the industry instead of relying on men from outside who had received training and acquired familiarity with equipment divorced from the needs of coal mining.

Secondly, by the mid-1960's local manufacture of LHD machinery had commenced. This development was important from two directions. Spare parts became more-readily accessible eliminating the necessity for local collieries to carry exaggerated stocks and reducing the burden on their own workshops and engineering resources. But perhaps more importantly local manufacture enhanced the stock of indigenous wisdom concerning all aspects of LHD-machinery operation and maintenance. Previously collieries had had to rely on the services of agents. Now, however, the advice and back-up of local engineers and assemblers was readily available.

Thirdly, and finally, important design modifications were made to machinery with the objective of rectifying the mistakes prevalent during the learning period. Two types of modifications were evident. In the first instance adaptations were performed to prevent the more-common forms of abuse resulting from non-machine-conscious operators, and, in the second instance, extensive re-design of features was undertaken to either eliminate or drastically reduce the volume of repairs stemming from failure of rapidly-wearing parts. Obviously, too much space cannot be devoted to the discussion of details but a few instances will suffice in relation to the re-design of shuttle cars. Operator abuse in the form of lugging or stalling the engine was eliminated through the introduction of the torque convertor which also provided smoother acceleration and the consequent reduction of the shock-load on gears and shafts. In addition, the common abuse of reversing the vehicle while tramming forward was eliminated through the introduction of hydraulic pressure which locked the gear lever in the selected position as soon as the car moved and was only released when the vehicle became stationary. Particular attention was paid to the positioning and mounting of the engine(s) and drive shafts so as to provide maximum protection from damage. Critical structural areas were strengthened to provide freedom from frame repair. Hydraulically-powered four-wheel steering was introduced. Quick-shift hydraulic clutches were provided with provision for outer-wear compensation. Gearing was the subject of much research and experimentation, the Torkar boasting "helical spur gears made of high-grade alloy steel, precision cut, crown shaved and heat treated". Obviously, the ultimate solution to rapidly-wearing parts is to eliminate them entirely, if possible. The Ramcar, introduced in 1967, was remarkable in that it eliminated four particularly troublesome items - trailing cables, cable reels, steering linkage, and conveyor chains, these being replaced by "simple and rugged devices which require little maintenance" according to the manufacturer's publicity.

1975 - 78: Learning, Open-Cast, Continuous Miners etc.

It may well have been the case that the industry could have continued enjoying increasing productivity after 1974, benefiting from the wisdom accumulated with LHD machinery, but for the exogenously-imposed dictates of the 1973 Arab-Israeli War. The subsequent oil crisis and the tremendous increase in the demand for coal both domestically and from overseas necessitated the introduction of a new coal-extraction technology capable of meeting the challenge of a vastly stepped-up production objective. Quite simply, conventional LHD technology could not extract the coal fast enough and so the industry turned to open-cast, continuous miners, and longwalling as a means of meeting the challenge.

As a result, increasing productivity was abruptly transformed into declining productivity as the industry entered into another era of learning comparable in many ways with the LHD learning period of 1959-67. Over the four-year period 1975-78 output increased at an average annual rate of 7,4 per cent in comparison with only 4,2 per cent over the previous nine years. Unfortunately, the industry was far less successful in controlling the average annual increase in input which rose from 2,0 to 12,1 per cent. All components of total factor input experienced increased growth rates. As would be expected during a period of heavy capital expenditure there was a large rise in the growth rate of the capital stock from 4,2 to 12,6 per cent per annum, but the main offender was raw materials, rising from 3,9 to 21,0 per cent per annum.

In common with the LHD learning period the industry once again lost control of the growth of spares and repairs inputs which rose to an average annual rate marginally under 30 per cent. The reasons were the same as before, namely, sub-efficient machine design, and management and employee unfamiliarity with the new equipment and techniques.

Industry management made the same mistake as with the introduction of LHD machinery in that equipment was imported into South Africa, mainly from the United States, which had been developed with regard to conditions prevailing overseas and put to work with no modifications. With regard to LHD machinery the problem lay with the non-machine-conscious labour which was expected to operate it, but with regard to the new technology, in particular continuous miners and longwall equipment, the problem lay in the different abrasiveness of South African coal. Local coal is far harder than that experienced overseas and the imported equipment was not robust enough and lacked the cutting performance necessary to effectively mine the coal. Excessive breakdowns resulted from violent vibrations induced in the equipment, and undue stress was placed on all working parts. In 1978, 50 per cent of total breakdown-time recorded with continuous miners was attributed to cutter-head problems with 20 per cent attributed to interconnection trouble, for example, hoses. Electrical failures were also experienced followed by a host of other common problems. Longwall equipment was also plagued by excessive pick wear, but other problems were also evident in the form of the robustness of roof-support equipment, and the snagging of cables and hoses. Open-cast mining did not escape the escalation of spares and repairs inputs. The problem lay not so much with the dragline itself as with the ancilliary machinery used for mining and transporting the exposed coal such as drills, power shovels, earthmovers, and coal-haul trucks. With this equipment working uninterrupted for many hours it is not surprising that frequent breakdowns should occur. Tyre wear on the 150-tonne coal-haul trucks has been described as "phenomenal" (5). Each of the ten tyres on these haulers cost R8 000 in 1977.

Not surprisingly the human element must also share some blame for the escalation in spares and repairs inputs during this period. Whilst black labour could not be accused of lack of machine-consciousness, as during the LHD learning period, they were certainly unfamiliar with the new equipment they were expected to operate, and experience in efficient handling had to be acquired slowly and costly. Unfamiliarity was also a problem with white artisans and management. The costly nature of the equipment implied that stand-by machinery was invariably not available and to recoup the huge initial capital outlay management was obliged to operate it to the maximum. This presented difficulties in regard to the maintenance of these machines. Representatives of the manufacturers were usually of the opinion that the major cause of breakdowns was inadequate maintenance (6). Management unfamiliarity was also evident in several directions. Choice of equipment was often difficult. With several manufacturers competing keenly in the area, often offering a choice of equipment and design, machine selection was made very difficult, especially by managements often unsure of their exact requirements. In addition, managements performed trial-and-error experimentation to discover the most efficient operation of the new machinery and the type of geological circumstances to which it was best suited. The mistakes were many but the experience gained was immense. Unfortunately, the burden imposed by breakdowns was heavy.

1979 - 80: Familiarity, Open-Cast, Continuous Miners etc.

By the end of 1978 the learning period had been completed. Over the two-year period 1979-80, the average annual increase in output rose to 10,4 per cent from 7,4 per cent recorded during the previous four-year learning period, whilst total factor input fell back from 12,1 per cent annually to 4,5 per cent. The net result was a 5,3 per cent average annual increase in total factor productivity. A significant observation is the difference in length of the two learning periods : nine years in the former case (1959-67), as compared with four years in the latter case (1975-78). Obviously, it was a matter of "learning faster" amongst all personnel involved in the industry - management, manufacturers, and workers.

Reductions were observed in the rate of increase of all input components during the 1979-80 period. Labour employed actually fell, but the most significant change was the dramatic fall in the rate of increase of raw materials from 21,0 per cent to 7,5 per cent annually. This is basically attributable to the fact that the industry gained control over its spares and repairs escalation which fell from approximately 30 per cent per annum to an average of only 9,8 per cent.

The same three explanations offered previously account for this upturn in productivity, namely, personnel familiarity, local manufacture, and equipment re-design.

It appears obvious that the "new deal" offered to black mineworkers, evident in the late 1970's, has had a favourable impact on machine-consciousness, motivation and productivity. Increased wages, better living and working conditions, the granting of re-engagement certificates, greater emphasis on local recruiting, more-generous leave conditions, the provision of more married accommodation and local township housing, the commitment to abolish job reservation, the admission of black registered trade unions, and increased emphasis on more-specific machine-related training programmes are all issues which have been discussed in chapter 5, and the result has been a smaller black workforce, but certainly more highly paid, motivated, stable and technically skilled in machine handling. Several of these factors were becoming evident from 1974 onwards rather than abruptly occurring after 1978, but their combined impact only climaxed in more-favourable productivity growth in the last years of the 1970's and probably explain why the learning period was restricted in length to only four years.

As compared with the LHD familiarity period these issues represent a major change in concept in the treatment of black mineworkers. LHD familiarity was mainly achieved through "learning by doing" and specific training, whilst still operating within the confines of the "old deal" offered to black labour. On the other hand, it may be the case that this new familiarity period owes a major contribution to a change in black attitudes and motivation resulting from their improved treatment.

Extensive local manufacture and re-design of equipment used in longwalling, continuous mining, and open-cast mining have also characterised the post-1978 period. The development of equipment specifically to meet South African geological conditions basically came about through trial and error, but was considered essential if operating costs were to be reduced and productivity raised. Spandau (7) reported a case study in 1979 where one particular company (Joy) employed twenty draughtsmen to adapt imported machinery to local conditions. "Mutations" to new machinery were not only affected by the distributor, but by the purchaser as well. "Through a process of trial and error, users locate operating bugs and modify equipment so as to suit local requirements. Typically, these changes are regarded as too minor to be formally recorded, yet often the final installation differs considerably from initial design". Spandau reports several examples of mutations with the objectives of modifying equipment either to suit local geological conditions, or to suit local labour conditions (what he calls "fool-proofing") such as de-rating the gears on driving equipment. As far as local manufacture of equipment is concerned this has generally been pursued with the objective of maximising local content in order to ensure an effective back-up of spares and after-sales service.

Much of the praise for the post-1978 modifications to continuous miners is due to the research efforts of the Coal Mining Laboratory of the Chamber of Mines' Research Organisation which in early 1978 commenced upon a programme of developing a modified continuous miner to overcome the major problems which collieries had been experiencing with this machine associated with lack of robustness and cutting performance in the harder and more-abrasive South African coal and the subsequent proliferation of breakdowns and extensive downtime. The research programme was four-pronged. In the first place the Laboratory studied the production results of continuous miners in South African coal mines. It monitored monthly colliery reports and data relating to the types of units operating, overall rates of production, the hours of machine and section downtime and their causes, in order to gauge the effectiveness of the machines in different practical applications. Secondly, the Laboratory operated a modified experimental continuous miner on field trials at Kriel colliery where detailed quantitative information on the effects of different drum speeds, the spacing of the tungsten-carbide picks on the drum, and the sumping and shearing forces in the performance of the machine was collated and combined with results obtained from laboratory tests. This laboratory work constituted the third prong of the research programme and was conducted to determine the basic parameters for various types of coal of the relationship between depth of cut, triaxial force distribution by the picks, and energy requirements. Finally, the cutability of the coal seams themselves was investigated with the objective of producing a "cutability profile" of the coal found in different parts of the country so as to dictate the design specifications required of the continuous miners used on those seams.

Joy Manufacturing (Africa) pioneered the local production of continuous miners, announcing the decision in late 1978. The unit concerned was the 12CM6 model which Joy had been metricating and modifying since mid-1977 to suit the more-rugged South African conditions. The first locally-manufactured unit entered production in September 1979. The machine weighed 45 tonnes, with a local content of 90 per cent by mass and 64 per cent by value. Joy engineers have greatly benefited from experiments carried out by individual collieries in collaboration with the manufacturers. Major variations have been tried in the areas of pick qualities, pick spacings, and drum speeds. Joy has carried out its own experiments with pick spacings, moving successfully from 375 to 750 millimetres, although retaining the 375 spacing in a few collieries. A major re-design feature of the locally-manufactured 12CM6, performed by Joy engineers in close association with mining engineers, has been to modify the hydraulic system to reduce the boom-raising time by up to 50 per cent, which has greatly improved the operating performance of the miner. This unit was followed by the delivery to Bosjesspruit in late 1980 of the heavier 58-tonne Joy 12HM9. Being heavier and more rugged, this new machine stands up well to vibration which has resulted in lower maintenance and higher availability.

Other manufacturers of continuous miners have followed Joy in the direction of local manufacture and feature re-design to improve ruggedness, an example being the Marietta 3080, but it is not necessary to prolong discussion of the details of these developments.

A point worth mentioning concerns difficulties which used to be experienced in transporting the coal extracted by a continuous miner. The working time of a miner was often restricted because the shuttle cars operating behind it could not move the coal fast enough or else problems were encountered in hoisting the coal smoothly and continuously onto the conveyor system. This has effectively been solved by the innovation of a "bridge" behind the miner linking it to the haulage system, and, hence, eliminating shuttle cars entirely. This high-volume haulage efficiency was one of the major problems in the evolution of continuous mining. A particularly successful installation has been the Jeffrey 5010 continuous-haulage system at Sigma colliery introduced by the Jeffrey Mining Machinery Division of Dresser Industries, making possible production rates of ten tonnes per minute.

The movement towards local manufacture and feature re-design has also been evident in longwall equipment (but to a lesser extent in open cast machinery particularly the draglines themselves). South African longwalling collieries are able to take advantage of equipment which has been designed in Europe and developed and tried over many years in their mines. Much of the technology originates from Germany and Britain but has been successfully adapted for South African use by re-designing several features. Many separate items of equipment are involved in the mining process and modifications are generally too detailed and technical to warrant discussion for the purpose of this thesis.

Recommendations

Consequent to the arguments in conclusion (3), some blame must be attached to industry management for the developments experienced during the learning periods. Although increases in the growth rates of capital stock and spares and repairs are only to be expected during years when new technologies are being introduced, management must be faulted for their misjudgement in either ignoring or under-estimating the adverse developments which occurred during the learning periods. This lack of realisation manifested itself in the absence of any concerted, co-ordinated pre-planning. In particular, personnel were not prepared for the coming changes. One cannot but conclude that the subsequent problems experienced could, at least, have been partially nullified through prior anticipation of them and the subsequent framing of a co-ordinated policy programme which would have stemmed from this.

In addition to this lack of prior planning, the reaction of the industry to problems as they occurred was sub-optimal. Individual colliery managements, unfamiliar with the new techniques and with very few guidelines to assist them, were left to learn by themselves. Accordingly, a situation developed of mine-to-mine ad hoc reaction to teething and other problems. This type of trial-and-error, crisis-type management proved extremely inefficient and costly. The experience with continuous miners was typical. Individual mines tended to make modifications to suit their own particular situation, setting different objectives and using varying criteria in measuring the performance of their machine. Accordingly, little uniformity and diverse results were obtained, making comparisons between collieries difficult as well as the task of finding an objective yardstick. In this unco-ordinated situation barely any common threads could be discerned to provide practical assistance in developing principles and guidelines which would be useful in selecting and operating machinery for specific applications. In addition, the knowledge which was accumulated in individual collieries was poorly disseminated throughout the industry. In fact no formal method exists. Patchy, ad hoc dissemination (often by word of mouth) was even confounded in many cases by confidentiality. Perhaps not surprisingly individual mining houses have been reluctant to disclose information emanating from trials. One large mining house which extensively tested a continuous miner in the late 1960's treated the results as confidential, thus denying other interested parties the benefit of their experience, and forcing them into the same costly routine to obtain what should have been readily-available information. Of course, this behaviour is understandable in view of the keen competition between the mining houses, but it hardly contributes towards a shortening of the industry learning period.

Two recommendations stem from these observations. Firstly, industry management must learn from the experience of the past and anticipate rather than ignore the adverse developments encountered during learning periods. This realisation must then manifest itself in a policy programme designed to minimise these consequences. Secondly, there must exist a formal, co-ordinated industrial pooling of knowledge, especially during periods of new-technology introduction, and the efficient dissemination of this wisdom to concerned parties. Individual mining houses can hardly be expected to provide such a service. Rather the Chamber of Mines is ideally situated in this regard. The Coal Mining Laboratory could be persuaded to extend its traditional areas of research to assume responsibility for this co-ordinating role, with results being made available in the form of open, rather than limited, circulation reports and through other formal methods of information dissemination.

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(3) See "Should South African Coal Mines be Mechanised?" op cit., pages 26-28; and Papendorf, O.L., "The Controversial Question of Mechanisation", Parts 2 and 3, published in Coal and Base Minerals of Southern Africa, June 1954 (pages 28-30) and July 1954 (page 30), respectively.

(4) Papendorf, O.L., "The Controversial Question of Mechanisation", Part 3, op cit., page 32.

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