INPUTS, OUTPUTS AND PRODUCTIVITY CHANGE IN THE AUSTRALIAN SHEEP INDUSTRY

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Tornqvist quantity indexes of output and input are computed for the period 1952/53 to 1976/77 from Australian Sheep Industry Survey data. The computation includes estimating the annual service flow from durable inputs. Total productivity in the sheep industry is estimated to have increased by 2.9 per cent per annum during this 25-year period. While the ratio of capital employed per unit of labour has increased, materials, services and livestock have been the inputs for which the quantity used has increased most rapidly. On the output side, there has been a move towards greater diversification with both crop and cattle enterprises on 'sheep properties' increasing in relative importance.

Introduction

It has been broadly accepted that productivity gains have been an important means of ameliorating the income-eroding effect of the decline in farmers' terms of trade (i.e. the prices received to prices paid ratio) (BAE 1978). However, little is known about the process of productivity change in Australian agriculture. The analysis presented in this paper contributes to an understanding of productivity change by assessing the extent and nature of such change for the Australian sheep industry between 1952/53 and 1976/77. An analysis of past productivity change provides a guide to the likely nature and extent of such future change.

In the sheep industry, as with any multi-output, multi-input industry, it is essential to examine movement in total output relative to total input (i.e. total productivity) to measure productivity change. Hence, total productivity (i.e. total output per unit of total input) is employed in this paper as a measure of overall sheep property productivity. Partial productivity measures (i.e. quantity of outputs or some subset of outputs with respect to some subset on inputs) are very sensitive to both the composition of output and the relative intensity of various inputs. For example, if capital were being substituted for labour, the partial productivity of labour would be increasing more rapidly than that of capital. Similarly, if the importance of wool in farm output were declining relative to beef, the quantity of beef produced per unit of any farm input would have increased more rapidly than the quantity of wool per unit of the same input. In fact, it is quite conceivable that the quantity of wool produced per unit of total farm input could have fallen during the same period in which the ratio of wool output per unit of input to the wool enterprise increased. Hence, while partial productivity measures are seen as having a role in indicating how the relationship between selected inputs and outputs has changed, they must be interpreted with caution.

Tornqvist quantity indexes of various input and output categories as well as total input and total output were computed using data from the BAE's survey of the Australian sheep industry for the years 1952/53 to 1976/77. While it is ackowledged that there is considerable variability between properties, all data given here are on an average per property basis.[1] To generate measures of sheep industry output and input, the average property data given in this paper must be multiplied by the total number of properties in the industry. However, as the productivity measures which constitute the main focus of this paper are ratios of quantities, they will be the same for both the industry and the average property.

These quantity index series are employed here in an analysis of trends in total productivity as well as relative movements in various types of outputs and inputs for an average property in the Australian sheep industry. Since the threshold eligibility criterion for participation in the ASIS is the possession of more than 200 sheep, and because of the association of sheep with other enterprises, this analysis relates to the majority of Australia's grazing and broadacre cropping properties.

The methodology employed and its relationship to that of related past studies is the subject of the next section. Tornqvist quantity indexes of various outputs and inputs of the average sheep industry property are given in the third section. The penultimate section contains an analytical review of productivity change and relative movement of selected inputs and outputs.

Methodology

Past papers on the subject of productivity change in Australian rural industries have generally not dealt fully with the problem associated with identifying and measuring the service flow from durable inputs. Young (1971) studied the productivity change in Australian rural industries between 1948/49 and 1967/68 by means of the Solow ratio method (Solow 1957) and obtained a trend annual rate of growth of productivity of 1.9 per cent. In the Solow approach inputs are combined geometrically and, hence, the method is unlikely to be realistic as it is based on the assumption of unitary elasticity of substitution between inputs (Arrow, Chenery, Minhas and Solow 1961; Griliches 1963).

Glau (1971) examined the movement of net farm income between 1949 and 1969 and concluded that, in the 1960s, productivity increases were sufficient to offset the adverse price movements. While the issue of productivity change as an important aspect of adjustment was raised by Glau, productivity change as such was not examined in detail.

Two more recent contributions were made by Hoogvliet (1973) and Easter, Spillman and Scougall (1977). Hoogvliet examined productivity in the sheep industry between 1957/58 and 1970/71 using the Lydall method (Lydall 1968) and further developed the theme of productivity change as an important aspect of adjustment. Easter et al. updated these results and suggested that input deferment was an important source of apparent productivity gain in the sheep industry during the mid-1970s.

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[1] Average per property figures are derived as an appropriately weighted average of ASIS survey data. The weights are dependent upon the number of survey properties which have a given number of sheep and cattle relative to the number of such properties in the total population. Hence, they represent an industry average rather than a simple sample mean.

Griliches (1960) and Griliches and Jorgenson (1966) have discussed the problems of measuring productivity change, particularly in relation to measuring the service flow from durable inputs. The methodology adopted in this paper is an attempt to take account of these difficulties along with those associated with the multi-output, multi-input nature of the Australian sheep industry and the presence of intermediate goods such as stock on hand.

To form a measure of the quantity of total output (input) for the average sheep industry property, it is necessary to combine the quantities of each component of output (input).

The customary means of combining heterogeneous outputs (or inputs) is by adopting some index number procedure. There are several alternative feasible index formulae available. One which has been frequently used is the Laspeyres index (Christensen 1975). This index takes the change in total output to be the sum of changes in component output quantities weighted by base year prices. However, the Laspeyres index number approach involves the implicit assumption that there is a linear production function so all factors of production are perfect substitutes and all outputs are perfect substitutes (Christensen 1975, p. 911). Such an assumption implies that a decline in the relative price of any output would lead to its not being produced. To the extent that the Laspeyres indexing method does not accurately describe the nature of the production process, the results of employing this procedure for measuring productivity change will be incorrect.

The index number formula employed in this study is that developed by Tornqvist (1936). This index is quite flexible as it is based on a homogeneous translog production function which provides a second-order approximation to an arbitrary production function at any given point (Christensen, Jorgenson and Lau 1973). It can precisely reflect an arbitrary set of substitution possibilities at any given feasible point.

In log-change form, the Tornqvist index formula is

$$\log (Q_t/Q_{t-1}) = \sum_{i=1}^{N} v_{it} \log (q_{it}/q_{it-1})$$

where

$$v_{it} = (p_{it} \ q_{it} / \sum_{j=1}^{N} p_{jt} \ q_{jt} + p_{it-1} \ q_{it-1} / \sum_{j=1}^{N} p_{jt-1} \ q_{jt-1})/2,$$

p_{it} is the price of item i at time t, q_{it} is the quantity of item i at time t, and Q_t is the total output at time t.

Hence

$$Q_t = Q_{t-1} \text{ antilog } (\sum_{j=1}^{N} v_{it} \log (q_{it}/q_{it-1})).$$

Furthermore, the Tornqvist index is approximately consistent in aggregation, i.e. an overall Tornqvist index of Tornqvist indexes of subaggregate groups is approximately equal to a Tornqvist index of all the basic components within those subaggregate groups (Diewert 1975). Christensen and Jorgensen's (1973, p. 261) claim that the Tornqvist index is consistent in aggregation is not universally correct.

Outputs and Inputs

There are five major categories of sheep property output — crops,

wool, sheep (non-wool), cattle, and other. The individual components of each of these groups are documented in the Appendix. The results obtained for the quantity indexes for these five output groups and total output are contained in Table 1.

Total output produced by the average sheep industry property has increased by 4.4 per cent per annum during the period 1952/53 to 1976/77 (Table 5). The only major departures from this upward trend occurred during the drought-affected years of 1965/66, 1967/68 and 1972/73 (see Figure 1). In contrast, the implicit index of total prices received, which has been derived by dividing the value of total output by the corresponding Tornqvist quantity index, has increased very little.

During this 25-year period, the average sheep industry property has become more diversified. Crop and cattle enterprises have increased in relative importance, with their output increasing by 6.8 per cent and 6.5 per cent per annum, respectively. Although production of wool and sheep has declined in relative importance, the quantity of wool produced by the average property has still increased by 2.2 per cent per annum.

Inputs have been similarly classified into five groups—livestock, materials and services, labour, capital, and land. The individual components of these input groups are given in the Appendix.

In measuring the contributuon of durable inputs to farm production, an attempt is made to quantify the service flows and the cost of such ser-

TABLE 1

Output Quantity Indexes

(average per property)

| Year	Crops	Wool	Sheep (non-wool)	Cattle	Other outputs	Total output	Implicit total prices received
1952/53	80.4	70.6	72.0	63.0	69.0	70.2	132.1
1953/54	93.7	70.6	65.1	62.3	78.3	70.8	125.6
1954/55	77.5	73.0	70.7	68.0	91.0	72.4	115.1
1955/56	98.4	82.0	79.0	84.6	79.0	82.1	106.3
1956/57	64.7	88.3	85.7	88.7	78.5	83.9	132.1
1957/58	52.6	86.0	80.4	87.3	104.2	80.8	106.0
1958/59	117.4	93.5	86.3	106.0	94.1	96.5	88.9
1959/60	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1960/61	141.8	96.6	96.3	137.9	94.7	106.8	99.7
1961/62	136.8	102.3	104.1	137.8	121.2	111.7	96.7
1962/63	167.8	100.0	108.4	155.0	122.0	117.3	103.0
1963/64	187.6	108.5	115.0	155.6	123.6	126.1	114.8
1964/65	193.2	109.6	106.6	153.7	153.9	126.2	106.4
1965/66	126.8	97.9	95.9	136.8	150.7	107.4	111.9
1966/67	241.7	108.6	116.4	117.2	165.8	131.2	112.3
1967/68	137.4	107.4	112.7	148.0	248.3	122.5	102.3
1968/69	305.5	116.9	131.7	189.5	257.8	160.5	105.2
1969/70	238.9	123.7	126.6	222.3	255.4	158.8	92.2
1970/71	182.0	116.8	107.1	282.1	336.9	157.4	84.9
1971/72	215.9	115.8	130.6	314.3	357.8	172.6	90.1
1972/73	174.6	111.7	124.2	283.7	310.7	157.9	142.7
1973/74	235.4	123.8	114.3	319.7	327.6	173.2	173.1
1974/75	308.2	126.7	109.4	241.5	357.8	179.9	122.8
1975/76	326.7	125.2	109.1	295.6	391.9	188.2	132.6
1976/77	449.7	112.6	117.8	270.7	489.3	212.7	147.1
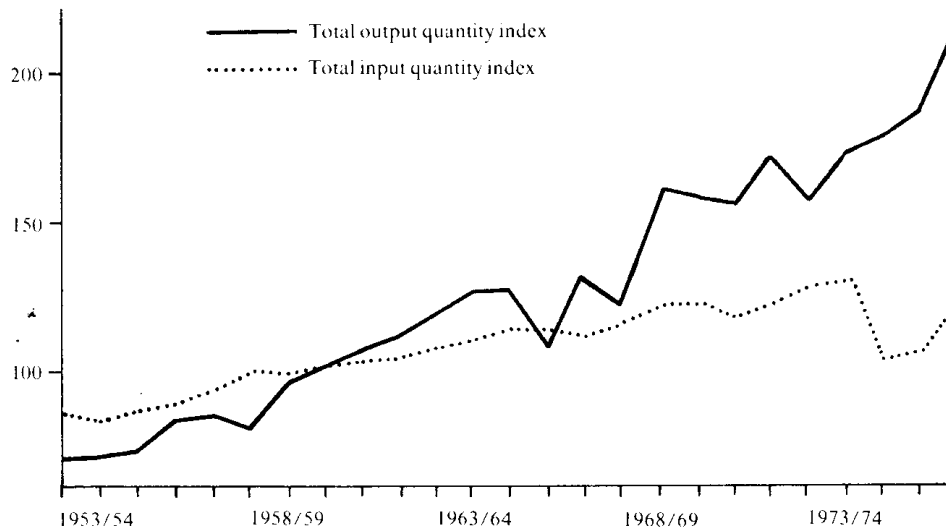
FIGURE 1 — Movements in the quantities of total outputs and total inputs
(average per property).

vice flows to the producer on an annual basis. Durable inputs are contained principally in the livestock, capital and land groups. The initial purchase price of such inputs is influenced by their production cost together with the expected value of the flow of services which that input will supply over its lifetime. Hence, it is not appropriate to attribute the total cost of such an input to the purchase period but rather to allocate the service flow from the durable input over its complete lifetime. This means that, while purchases of durable inputs will be concentrated in certain periods, the flow of services from durable inputs will be less bunched (Waugh 1977). A more extensive discussion of service flows and their cost is presented in the Appendix.

Owing to data limitations, the quantity of service flow from durable inputs is taken to be proportional to the current quantity of the stock of such inputs.[2] In the case of capital, the stock quantity was derived by dividing the current replacement value by the Bureau's relevant index of prices paid. In contrast, direct measures of the stock quantities of land and livestock are available. The quantities of durable inputs are then weighted by the costs of deriving the respective service flows to form quantity indexes. The cost of obtaining the service of durable inputs can be divided into three components, depreciation, maintenance and opportunity cost. Although it can reasonably be argued that the operating expenses are a cost in obtaining the services of certain durable inputs, such as plant and machinery, they have been treated as separate inputs here.

The quantity of total inputs used by the average sheep industry property has exhibited only a moderate increase of 1.5 per cent per annum over this 25-year period. Materials and services increased at 2.8 per cent per annum, while the quantity of capital input, excluding livestock and land, increased at 1.1 per cent per annum (see Table 5). There has been no significant trend in the total quantity of labour employed by the

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[2] It is acknowledged that this procedure will not always generate an accurate measure of the service flow (Yotopoulos 1967).

TABLE 2

Input Quantity Indexes

(average per property)

Year	Livestock	Materials and services	Labour	Capital	Land	Total inputs	Implicit total prices paid
1952/53	73.7	85.6	84.8	80.4	101.0	84.7	83.7
1953/54	55.0	89.0	86.4	83.9	101.3	82.6	88.8
1954/55	75.7	85.8	87.4	87.0	101.4	86.9	85.1
1955/56	85.6	85.4	88.0	87.2	101.5	88.9	89.1
1956/57	89.4	90.8	91.9	88.8	101.7	92.3	97.2
1957/58	95.1	100.0	99.7	101.4	98.9	99.4	99.2
1958/59	89.7	94.1	98.9	100.9	99.3	96.7	98.4
1959/60	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1960/61	109.6	104.8	97.7	99.2	100.9	102.1	106.5
1961/62	108.8	108.2	99.3	100.6	101.7	103.7	108.1
1962/63	116.2	114.1	100.8	101.6	101.9	106.9	107.7
1963/64	118.7	127.1	93.4	103.8	102.6	109.0	108.8
1964/65	127.3	136.7	91.9	108.2	99.0	112.5	118.1
1965/66	134.2	132.9	88.4	110.4	99.2	112.2	123.8
1966/67	106.0	141.9	91.5	110.2	101.8	111.0	128.0
1967/68	113.9	138.6	89.0	132.3	103.4	114.7	136.4
1968/69	142.6	145.4	92.9	128.6	103.6	120.8	140.1
1969/70	151.7	142.2	91.4	129.2	103.6	121.0	144.2
1970/71	158.4	133.5	86.8	125.1	100.6	117.3	147.8
1971/72	186.9	138.8	90.7	114.4	105.9	122.0	149.7
1972/73	165.5	163.7	88.5	118.1	114.5	127.1	164.6
1973/74	135.8	180.9	97.5	126.2	115.5	130.2	211.8
1974/75	96.5	127.7	84.7	81.5	124.9	103.7	244.3
1975/76	116.8	132.0	88.5	84.7	117.3	106.6	278.7
1976/77	140.9	157.7	91.1	106.3	125.1	121.2	303.8

average sheep industry property, although an increasing proportion of this has been family and contract labour at the expense of hired labour. Hence, there has been an increase in the ratio of capital input per unit of labour employed.

Variations about these trends in input use reflect the combination of (a) producers' decisions in the face of prices, available production technology and physical and financial constraints, and (b) sample error. While there was a decrease in the use of materials and services and an apparent running down of the capital base in 1974/75, some of the change indicated in Table 2 is probably due to change in the survey sample.[3] Evidence of the influence of such sample changes can be seen in the series of land inputs for the average farm during the mid-1970s.

Productivity Changes

An index of total factor productivity was derived by taking the ratio of the total output to total input quantity indexes. Similarly, a prices received to prices paid ratio index was derived by taking the ratio of the im-

[3] The capital data for 1974/75 and 1975/76 suffer from the replacement value used in the survey not keeping pace with actual replacement prices for some of the properties that were continuously in the survey. Together with variations in the sample, this appears to have led to an exaggeration of the drop in capital input in these two years. However, this problem was rectified in 1976/77 when a complete revaluation of all survey capital data was undertaken, bringing survey valuations back into line with actual replacement prices.

plicit total prices received to total prices paid indexes. These results are presented in Table 3 and Figure 2. The returns to costs ratio listed was derived by indexing the ratio of the value of output to the value of input.

Total factor productivity has shown an annual rate of increase of 2.9 per cent over this period. Productivity fell noticeably below trend in 1957/58, 1965/66, 1967/68, 1972/73 and 1973/74, due largely to reductions in total outputs associated with drought conditions in the first four of these years and a relatively high level of input usage in 1973/74. This high level of input usage is explainable by a catching up of inputs deferred from earlier, less favourable years and advanced investment in inputs for following years in this period of relative boom conditions (Waugh 1977). This pattern of input usage reflects the fact that the purchase of inputs is influenced by liquidity levels and taxation considerations. In contrast, productivity was above trend in 1958/59, 1968/69 and the final three years of the period. The years 1958/59 and 1968/69 were characterised by high levels of crop output while the increase in productivity in 1974/75 was due largely to a drop in the average quantity of inputs used. Particularly large falls occurred in the materials and services and capital input groups at this time.

These fluctuations of productivity around the longer term trend suggest that not too much emphasis should be placed on year-to-year or short-term movements. Seasonal effects and also advancement and deferment of inputs are likely to cause short-term departures from the long-term trend. Because of the unpredictable nature of short-term influences, more confidence can be placed in long-term trends than in short-term movements.

The implicit prices received to prices paid ratio has exhibited an annual rate of decrease of 4.1 per cent. The ratio had peaks in 1956/57, 1963/64 and 1972/73 but was generally declining over the period. The improvement in relative prices in 1972/73 coincided with the fall in productivity mentioned above. As implied by Jackson (1979), the precise nature of the
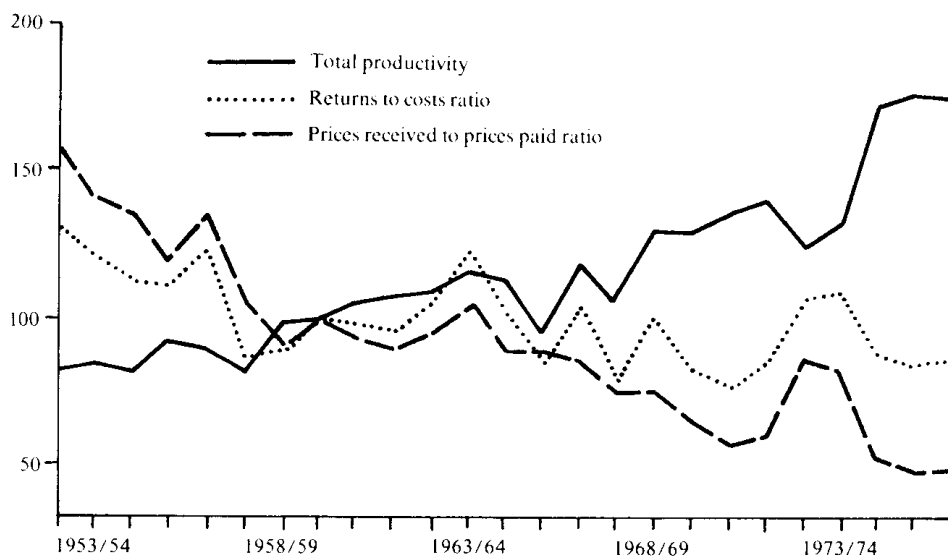

Figure 2 — Total productivity, prices received to prices paid ratio and returns to costs ratio movements, 1952/53-1976/77.

TABLE 3

*Total Productivity, Prices Received to Prices Paid Ratio
and Returns to Costs Ratio Indexes*

Year	Total productivity	Implicit prices received to prices paid ratio	Returns to costs ratio
1952/53	83.0	157.7	130.9
1953/54	85.7	141.5	121.3
1954/55	83.4	135.3	112.8
1955/56	92.4	119.3	110.3
1956/57	90.9	135.9	123.6
1957/58	81.3	106.9	86.8
1958/59	99.8	90.3	90.2
1959/60	100.0	100.0	100.0
1960/61	104.6	93.7	97.9
1961/62	107.8	89.4	96.4
1962/63	109.8	95.6	105.0
1963/64	115.6	105.5	122.0
1964/65	112.2	90.1	101.1
1965/66	95.7	90.3	86.5
1966/67	118.2	87.8	103.7
1967/68	106.8	75.0	80.1
1968/69	132.9	75.1	99.8
1969/70	131.2	64.0	83.9
1970/71	134.2	57.4	77.1
1971/72	141.5	'60.2	85.2
1972/73	124.2	86.7	107.7
1973/74	133.1	81.7	108.7
1974/75	173.5	50.3	87.2
1975/76	176.5	47.6	84.0
1976/77	175.5	48.4	85.0

relationship between productivity change and farmer terms of trade warrants further research.

The relationship between changes in productivity, farmer terms of trade, and the returns/costs ratio is illustrated by the following identity. At any given moment

The proportional rate of change in the returns/ costs ratio	≡	The proportional rate of change in the output/ input ratio	+	The proportional rate of change in farmer terms of trade.

The trend rates of change of the indexes generated in this study closely reflect this relationship. While the annual trend rate of change in the ratio of output to input was 2.9 per cent and the annual trend rate of change in farmer terms of trade was −4.1 per cent, the annual rate of change in the returns to cost ratio was − 1.2 per cent. As there has been a 4.4 per cent per annum increase in average property output, this means that returns to management, as measured by the difference between costs and returns, have increased by about 3 per cent per annum in nominal terms. There has been little change in real farm incomes. As this is an average figure, it does not preclude the possibility of certain producers, or even all producers in a particular geographic region, such as the Pastoral Zone, being unable to maintain the level of their farm income

throughout this period. In fact, these results conform with the results of earlier studies of the decline in real farm income relative to incomes in other sectors, due to the inability of rural productivity gain to counter the income-eroding effects of adverse relative price movements (Hoogvliet 1973: Dillon 1977).

The partial productivities of total output with respect to the five input groups are shown in Table 4. All these partial productivities increased over the period, with the major fluctuations occurring in the partial productivity of total output with respect to livestock inputs. The partial productivities of capital, labour and land all increased at levels higher than total productivity for most of the period. The partial productivities of both labour and capital increased substantially towards the end of the period.

Conclusions

Total factor productivity in the Australian sheep industry increased at an estimated annual rate of 2.9 per cent between 1952/53 and 1976/77. This resulted from an estimated annual rate of increase of 4.4 per cent in total outputs and of 1.5 per cent in total inputs. The advancement and deferment of inputs and seasonal conditions affecting outputs have been important causes of short-run fluctuations in productivity around the

TABLE 4

Partial Productivities of Total Output with Respect to Input Groups

Year	Total output/ livestock input	Total output/ materials and services	Total output/ labour input	Total output/ capital input	Total output/ land input	Total output/ total input
1952/53	95.4	82.1	82.8	87.4	69.5	83.0
1953/54	128.7	79.5	81.9	84.4	69.9	85.7
1954/55	95.6	84.4	82.9	83.3	71.4	83.4
1955/56	95.9	96.2	93.3	94.2	80.9	92.4
1956/57	93.9	92.4	91.4	94.5	82.6	90.9
1957/58	84.9	80.8	81.0	79.7	81.7	81.3
1958/59	107.5	102.5	97.5	95.7	97.2	99.8
1959/60	100.0	100.0	100.0	100.0	100.0	100.0
1960/61	97.4	101.9	109.4	107.6	105.9	104.6
1961/62	102.6	103.3	112.5	111.0	109.9	107.8
1962/63	100.9	102.8	116.4	115.5	115.1	109.8
1963/64	106.2	99.2	135.0	121.4	122.9	115.6
1964/65	99.2	92.3	137.3	116.7	127.5	112.2
1965/66	80.1	80.8	121.5	97.3	108.3	95.7
1966/67	123.8	92.4	143.4	119.0	128.9	118.2
1967/68	107.6	88.4	137.7	92.6	118.5	106.8
1968/69	112.5	110.4	172.7	124.7	154.9	132.9
1969/70	104.7	111.6	173.8	122.9	153.5	131.2
1970/71	99.4	117.9	181.4	125.8	156.5	134.2
1971/72	92.4	124.4	190.2	150.8	163.0	141.5
1972/72	95.4	96.5	178.4	133.7	137.9	124.2
1973/74	127.6	95.8	177.6	137.3	150.0	133.1
1974/75	186.5	141.0	212.5	220.8	144.1	173.5
1975/76	161.1	142.6	212.7	222.2	160.4	176.5
1976/77	151.0	134.9	233.6	200.2	170.1	175.5

underlying trend productivity increase. Total output quantity has increased at a relatively even rate, with minor fluctuations associated with seasonal conditions, while total input quantity has increased smoothly up until the final three years of the period when input usage dropped significantly.

The ratio of implicit total prices received to prices paid of the sheep industry, on the other hand, has decreased at an estimated annual rate of 4.1 per cent during this period. This has been brought about by an estimated annual rate of increase in total prices received of 0.5 per cent and in total prices paid of 4.6 per cent.

Between 1952/53 and 1976/77 the average sheep industry property has become noticeably more diversified. While the average farm output of cattle and crops has increased by 6.8 per cent and 6.5 per cent per annum, respectively, the average quantity of wool produced has increased by only 2.2 per cent per annum. As expected, there has been an increase in capital input per unit of labour employed, but materials, services and livestock have been the inputs for which the quantity used has increased most rapidly.

TABLE 5

Fitted Trends in Major Variables[a]
(average per property)

Variable	Parameter estimates[b]			
	Constant	Trend	R^2	DW
Output (Y)	4.215	0.044	0.96	1.87
	(149.41)	(23.29)		
Input (X)	4.469	0.015	0.74	0.86
	(162.70)	(8.12)		
Productivity (Y/X)	4.351	0.029	0.86	1.65
	(124.07)	(12.37)		
Output price (P)	4.657	0.005	0.04	0.87
	(65.27)	(1.00)		
Input price (W)	4.260	0.046	0.88	0.22
	(78.90)	(12.71)		
Terms of trade (P/W)	5.001	−0.041	0.84	1.31
	(88.00)	(−10.82)		
Returns/costs	4.664	−0.012	0.36	1.61
	(93.31)	(−3.62)		
Labour input	4.533	−0.001	0.02	0.84
	(198.53)	(−0.62)		
Capital input	4.498	0.011	0.26	0.75
	(81.24)	(2.87)		
Materials and services input	4.425	0.028	0.82	1.12
	(112.14)	(10.38)		
Wool output	4.333	0.022	0.84	0.81
	(145.75)	(10.95)		
Cattle output	4.120	0.068	0.91	0.87
	(61.65)	(15.09)		
Crops output	4.203	0.065	0.77	1.92
	(38.55)	(8.84)		

[a] Annual trend figures have been obtained by fitting the following logarithmic trend line by regression:

$$\ln y_i = a + bt + e_i$$

where y_i is the variable being considered and t is time.

[b] Corresponding t-statistics are given in parentheses.

APPENDIX

Data Specification

Stocks and services flows of capital

The main problem encountered in this study, as in other studies of this nature, has been the specification of the cost of deriving the service flow from durable inputs. 'Durable' inputs are defined as the components of the livestock, capital and land input groups. Durable inputs provide a flow of services into the production process over time, and so should be treated in a similar manner to durable consumer goods. Thus, for the year being examined, it is necessary to derive the cost of obtaining the flow input of a capital asset into the production process, as opposed to the cost of obtaining the complete flow of services for the life of the capital asset. The concept of service flow from durable inputs involves the distinction between the cost of using the input in a particular year and the value of the stock of that input in that year.

The cost of the annual service flow from capital can be divided into three components: depreciation (i.e. the amount of the capital good consumed in the production process in that year), maintenance and opportunity cost. The capital good may also be subject to a capital gain or loss which would reduce or increase the cost of using the capital good in that period. Capital gains/losses cannot be measured with the data available and are assumed to be of a magnitude small enough on average to be ignored without significant error.

In all cases, the quantities of service flows of durable inputs in any particular year are assumed to be a constant proportion of the quantity of the durable input stock in that year. This quantity of service flow is then weighted by the cost of deriving that service flow, as outlined above.

The level of aggregation and the concept of opportunity cost

The level of aggregation becomes critical when considering the concept of opportunity cost. If the average farm is used to represent the industry, then it is necessary to consider the value of a durable input outside the industry as the appropriate value from which to derive an opportunity cost. This means that durable inputs which can be used only in the sheep industry and not in any other industry will have zero value outside the industry and so would have no opportunity cost at this level of aggregation. On the other hand, highly mobile capital goods (e.g. tractors) will be of equal value outside the industry and so their opportunity cost should be derived from the full market value. This industry level of aggregation is beyond the scope of the data used in this study, since it would require detailed information on items such as the separation of intermediate sales of livestock from sales of livestock for final consumption. Consequently, the average per property data are used in this study to represent a typical farm in the sheep industry. Using this microeconomic approach, it becomes appropriate to derive the opportunity cost from full market value, since any capital good can be sold by the individual farm at its market price.

The annual opportunity cost of durable inputs was calculated by multiplying the current market value of the stock of the durable input by the rate of return relevant to the year being examined. The weighted

maximum annual overdraft rate was used to approximate the prevailing rate of return in the economy. While there are many rates of return on different types of investment of different durations, the overdraft rate was taken as being representative of the rate of return which could be expected from an alternative form of investment.

Specification of capital, land and livestock

Capital. The value weight given to the capital input group consists of two components: depreciation and opportunity cost. Maintenance of components of the capital group was included in the materials and services category. Opportunity cost was calculated by multiplying the value of the capital stock by the weighted maximum overdraft rate. Depreciation rates were derived for each of the components of the capital group from rates for individual capital items in the 1974/75 Australian Grazing Industry Survey. The quantity of capital inputs was taken as being proportional to the value of the capital stock divided by the Bureau's relevant index of prices paid.

Land. Being a basically inexhaustible asset, land was assumed to have zero depreciation, but it does require some maintenance in the form of fertiliser and management to avoid a reduction in its production potential. It is noted that soil erosion may lead to a reduction in productive capacity resulting from a lack of maintenance. These maintenance costs were included in the materials and services, and labour groups. Hence, the sole component of the weight given to the land input was opportunity cost. The quantity of land input was specified as the average farm size. Unfortunately, no data were available to take account of quality differentials of land used.

Livestock. The livestock input group represents a special case in that livestock are both an input and an output of the production process. While being a form of living capital, livestock are still subject to the same conceptual treatment as other durable inputs. Consequently, the livestock input quantity was represented by opening stock numbers. It was assumed that the average livestock unit does not depreciate but the maintenance of the zero depreciation situation requires two different forms of input. First, there are purchased inputs, such as drenches, as well as labour inputs associated with livestock maintenance. These maintenance inputs were included in other input groups.

The second form of livestock maintenance which must be taken account of is the replacement of herd or flock numbers which die or are disposed of as output. It was decided that the most suitable way of doing this, consistent with the capital nature of livestock, was to have livestock sales plus operating gains (where operating gains were positive) as an output, and livestock purchases plus the absolute value of operating gains (where operating gains were negative) as an input. Operating gains were defined as the difference between closing and opening numbers multiplied by the closing price. Positive values of operating gain represent output which is not sold, while negative values of operating gain may be interpreted as a running down of the capital stock in order to produce output. Hence the livestock output consists of one component where both the quantity and value weight are made up of sales plus positive operating gains. Livestock input has two components. The first of these is made up of purchases plus the absolute value of negative

operating gains in both quantity and value, while the second has opening stock numbers as the quantity and the opportunity cost of the opening stock value as the value weight.

Implicit quantities and data

As alluded to earlier, the Tornqvist index formula and productivity studies in general require both a quantity and a value (and, hence, an implicit price) for each component of input and output. In many cases it was not possible to derive a measure of physical quantity, due to the nature of historical BAE survey data. Under these circumstances, a 'quantity index' was derived by dividing the value of the component by the relevant prices paid or received index.

Specification of group components

The individual components of the five input and output groups are listed below. For each item a value and quantity were used.

Outputs

    Crops group — wheat
                  barley
                  oats
    Wool group — wool
    Sheep (non-wool) group — skin sales
                              sheep sales plus positive operating gains
    Cattle group — cattle sales plus positive operating gains
    Other outputs group — other returns

Inputs

    Livestock group — sheep purchases plus the absolute value of negative
                    operating gains
                cattle purchases plus the absolute value of
                  negative operating gains
                sheep opening stock
                cattle opening stock
    Materials and services — fuel and electricity
                      fertiliser
                      seed
                      fodder
                      packs and bags
                      drenches, dips and other chemicals
                      pest destruction
                      plant maintenance
                      freight and cartage
                      improvements maintenance
                      rates and taxes
                      insurance
                      droving and agistment
                      rent
                      interest
                      other costs

Labour group — hired labour and farm operation contracts
           imputed family labour
           shearing and crutching
           stores and rations
           operator's labour
Capital group — water
           fencing and yards
           buildings
           plant
Land group — land

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