THE RELATIONSHIP BETWEEN THE PRICE OF WOOL AND THE RELATIVE PROFITABILITY OF SHEEP AND CATTLE GRAZING IN AUSTRALIA AND ITS POSSIBLE EFFECT ON THE FUTURE SUPPLIES OF WOOL AND BEEF

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An estimate of the long term elasticity of supply for Australian wool has been made by establishing the price of wool at which 457 farms in the BAE Sheep Industry Survey (1964–5 to 1965–6) would find beef production more profitable than producing sheep and wool. The calculation suggests that the long term elasticity of supply would be of the order of 1·7 to 2·5 depending on the year on which the calculation is based.

The elasticities established in this way were used to estimate the long term supply of Australian wool assuming that the wool industry was exposed to prices similar to those prevailing in 1969–71 over a long period of time.

If future wool prices are of the order of 35 to 40 cents per lb, Australian wool production might decline by between 35 to 80 per cent and cattle numbers might increase by between 30 and 70 per cent at constant beef prices.

Any estimation of the future long-term production of beef and wool in Australia involves estimation of the long-term elasticities of supply for both commodities. Estimates of the long-term elasticity of the supply of wool were made by Gruen [6] in 1967 and by the Bureau of Agricultural Economics (BAE) [3] in 1971. Gruen calculated the elasticity of supply and cross elasticities of supply of wool, lamb, wheat, coarse grains, beef and veal and dairy products for the period 1947–8 to 1964–5. It was found that a competitive relationship existed between wool and wheat and there was some evidence that a similar relationship might exist between wool and prime lamb. No significant competitive relationship was found between wool and beef. The BAE study indicated that changes in the supply of wool over the period of 1926–7 to 1964–5 could be explained in terms of the price of wool, the price of wheat, and the area of improved pastures.

During both of the periods on which these studies were based the relative prices of wool and beef were very different to those prevailing in 1970–1 and those that might be expected in the future. Between 1951–2 and 1964–5, the ratio of wool prices to beef prices ranged between 5·72 in 1952–3 and 2·30 in 1958–9. The ratio altered drastically in the late 1960's. In 1967–8 it fell to 1·61 and in 1970–1 to 1·05. (See table 1.) If future wool prices are to be similar to those of 1969–70 and 1970–1 it is possible that a much more competitive relationship between beef and wool will exist than in the period examined by either Gruen or the BAE. It is possible that the ratio between beef and wool prices will be the dominant factor in determining the future supplies of wool and beef.

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TABLE 1

Ratio of Wool Prices to Beef Prices†*

1951–2	4·47
1952–3	5·72
1953–4	5·11
1954–5	4·22
1955–6	4·07
1956–7	5·40
1957–8	3·56
1958–9	2·30
1959–60	2·41
1960–1	2·18
1961–2	2·84
1962–3	2·89
1963–4	3·20
1964–5	2·38
1965–6	2·11
1966–7	1·86
1967–8	1·61
1968–9	1·69
1969–70	1·40‡
1970–1	1·05‡

* Wool price = average per lb for greasy wool sold by brokers in Australia.

† Beef price = average saleyard prices per lb liveweight quoted for Cannon Hill for ox/heifer 650–700 lb first and second export quality dressed weight.

‡ Estimated using BAE indices of prices paid and received by farmers.

Source: Bureau of Agricultural Economics, *Study of Supply Relationships in the Australian Sheep and Wool Industry*, Canberra, 1971, p. 20.

In these circumstances a more accurate estimate of the supply elasticity of wool might be made by finding the prices at which beef production becomes more profitable than wool production for a sample of farms which is typical of the Australian wool industry. If the number of farms which would still be producing wool at any one price can be estimated from a stratified sample of sheep farms, it should be possible to estimate the quantity of wool which would be produced in Australia at given wool and beef prices.

THE BASIC DATA

Surveys of 636 sheep farms in all of Australia's grazing zones were carried out by the BAE between 1963–4 and 1965–6 [2]. As a high proportion of farms in the surveys carry both sheep and cattle the survey data can be used to estimate the relative profitability of sheep and cattle grazing at different cattle, sheep, and wool prices. The total number of farms in the BAE sample carrying sheep and more than five head of beef in each grazing zone in each state is shown in table 2. The proportion which carried more than five head of beef cattle that could be included in the analysis was not less than 28 per cent of the total sample in any one zone and in most zones was much higher.

TABLE 2

Properties in the BAE Sheep Industry Survey, 1963–4 *to* 1965–6 *Grazing both Sheep and Cattle*

	No. of sheep properties in the population	No. of properties in the BAE sample	No. of properties with sheep and more than 5 cattle	No. with sheep and more than 5 cattle as percentage of No. in sample
	No.	No.	No.	%
Pastoral Zone—				
N.S.W. ..	3,761	50	35	70
Qld	2,992	53	44	83
S.A.	774	29	17	59
W.A. ..	353	22	8	36
Wheat-Sheep Zone—				
N.S.W. ..	23,361	106	81	76
Vic.	10,755	49	32	65
Qld	1,612	14	13	93
S.A.	7,963	34	15	44
W.A. ..	5,664	29	8	28
High Rainfall Zone—				
N.S.W. ..	8,677	61	55	90
Vic.	15,388	79	67	85
S.A.	4,344	31	27	87
W.A. ..	4,742	33	17	52
Tas.	2,827	46	38	83
Total	..	636	457	..

CHANGES IN WOOL PRICE AND THE RELATIVE PROFITABILITY OF SHEEP AND CATTLE

The decline or increase in wool price which would need to occur to justify changing from sheep to cattle on each farm in the survey with more than five cattle was established by dividing the change in profit which would occur if cattle replaced sheep by the total quantity of wool produced.

The increase or decrease in farm profit which would occur if cattle replaced sheep calculated on the above basis is summarized in equation (1):

$$(1)\ U = \frac{N}{8}(C - M) - W - G + V + L - K$$

Where

U = the change in farm profit obtained in changing from sheep to cattle,

N = the number of sheep equivalents carried,
C = gross trading returns per beast[1],
M = cattle marketing costs per beast,
W = value of wool and sheep skins sold,
G = gross trading returns from sheep[1],
V = variable costs associated with sheep,
L = decrease in wages paid, and
K = the annual cost of the capital required to change from sheep to cattle.

On each farm cattle were assumed to completely replace sheep at a ratio of one beast to eight DSE's[2]. The revenue from cattle trading and the cost of cattle marketing (the only variable cost associated with cattle) were increased in proportion to the number of additional cattle carried. In changing from sheep to cattle the following variable costs would no longer be incurred and were deducted from farm costs: shearing; crutching; wool marketing; sheep marketing; and, sheep veterinary medicines. In the BAE Survey, no differentiation is made between veterinary medicines purchased for sheep and cattle. As practically all of the livestock medicines purchased are used for sheep this item was charged entirely to the sheep enterprise.

Fixed labour requirements for maintaining fencing, water supplies, and other general work were assumed to remain the same when sheep were replaced by cattle. The decline in the amount of variable labour required if sheep were entirely replaced by cattle was estimated as 0·9 man days for each eight sheep equivalents replaced by one beast. The estimate is based on Tyler's work [10, 11] and details of its calculation are given in Appendix 1. It was assumed that casual labour could be reduced by any amount but that regular labour, including family labour, could only be reduced in whole man units and that the minimum amount of labour remaining on each farm was one man. By making these assumptions it was possible to estimate the decline in the wages paid on farms when cattle replaced sheep.

The annual cost of additional capital required on each farm to replace sheep with cattle assuming an interest rate of eight per cent was calculated using formula (2):

$$(2)\quad K = 0{\cdot}08N\left(\frac{B}{8} - S\right)$$

[1] Gross trading returns of sheep and cattle = (Sales + closing value)—(Purchases + opening value).

[2] The nutritional requirements of one steer are equivalent to those of 8 DSE. In a breeding herd the nutritional requirements of one cow and calf is equivalent to that of 15 DSE. With an 80 per cent calving percentage this is approximately equal to 8 DSE per beast carried. The ratio of one beast per DSE has been confirmed by experimental work in Australia [1]. Experimental work also indicates that at a given stocking rate live weight gains of beef cattle are the same whether they are grazed alone or in conjunction with sheep except in moist mountainous regions. Thus the effect of any complementary grazing relationship can be ignored in Australia [1, 4, 5, 7, 8, 9, 12].

Where:

K = the annual cost of additional capital required,

N = the number of sheep (in DSE's) on each farm,

B = the average values of each beast in the BAE grazing zone for the state in which the farm is located in each base year indexed to 1970–1 values using the BAE index off prices received by farmers for cattle, and

S = the average value of sheep (per DSE) in the BAE grazing zone for the state in which the farm is located in each base year indexed to 1970–1 using the BAE index of prices received by farmers for sheep.

As sheep would have to be sold in the open market and at least some of the additional cattle purchased in the same way, the average values of sheep and cattle for each grazing zone in each state rather than the individual values of sheep and cattle on each farm were used as a basis for formula (2)[3].

The decrease or increase in wool price which would need to occur to make grazing with cattle alone as profitable as mixed sheep and cattle grazing was calculated by dividing the estimated decrease or increase in profit (U in equation (1)) obtained on each farm in each year by the quantity of wool produced in that year. However, this procedure assumes that wool alone would decline in price. As the aim of the majority of Australian sheep farmers is to produce wool and not meat, one would expect that a decline in wool price would be accompanied by a decline in sheep prices. The exact ratio between these declines is unknown but it is reasonable to suppose that wool and sheep prices would decline in proportion to each other. In this situation the decline in wool price which would need to occur to make cattle grazing as profitable as sheep and wool production can be calculated by multiplying the decline in wool price required to justify the change at constant sheep prices by the proportion wool sales form of the gross trading returns from sheep plus the returns from wool. This procedure is summarized in equation (3).

$$(3)\quad Y = \frac{W}{W + G} \times \frac{U}{Q}.$$

Where:

Y = the decline or increase in wool price needed for equal profits to be obtained from sheep and cattle grazing assuming sheep and wool prices decline proportionately,

W = total gross returns from wool and skins,

G = total returns from sheep trading,

U = the change in farm profit obtained in changing from sheep to cattle (as calculated in equation (1)), and

Q = the quantity of wool produced per farm.

[3] Allowance should also be made for additional capital equipment required by cattle chiefly in the form of watering points and fencing. As the quantity required is unknown this factor has been neglected. Work in Victoria by Wills and Lloyd [13] suggest that error due to its omission would be small.

THE LONG TERM SUPPLY OF AUSTRALIAN WOOL AT LOW WOOL PRICES

The change in the price of wool needed to equalize the profits from grazing sheep or cattle and the price of wool which individual farmers might expect to receive at any particular average national wool price can be used as a basis for establishing the long term price elasticity of supply for wool.

The proportion of farms in each farm size stratum in each zone in the BAE survey on which cattle grazing alone would be more profitable than mixed sheep and cattle grazing can be calculated from equation (4).

$$(4)\quad X_i = \frac{F(Y > P)}{N_i} \times 100.$$

Where:

X_i = the percentage of farmers in each BAE farm size stratum changing to grazing cattle alone from mixed sheep and cattle grazing,

Y = the decline in wool price needed to make grazing cattle alone more profitable than mixed sheep and cattle grazing on a particular farm (as calculated in equation (3)),

P = the estimated price the same farmer would receive for wool at a particular average national wool price[4],

F = the number of farms where $Y > P$, and

N_i = the total number of farms in the BAE farm size stratum in each zone in each state.

As the price needed to justify changing from sheep to cattle varies with each of the 3 years of the survey the number of farms remaining in sheep will vary with the year of the survey selected as a base. The results of these calculations using each of the three survey years as a base year are shown in table 3.

[4] An estimate of the decline in prices which occurred for wool from each individual farm between the year of survey and 1970–1 was obtained by comparing the average price of wool received by each farmer in each of the years 1963–4 to 1965–6 with the national average prices of various classes of wool in the same years; the individual farmer's wool was then assumed to have declined in price to the 1970–1 by the same proportion as the class to which its price was most nearly equivalent in the three survey years 1963–4, 1964–5, and 1965–6. In 1970–1 the average price of Australian wool was 29·63 cents. The price which individual farmers would receive assuming the average price of Australian wool increased or decreased above or below the 1970–1 price was then calculated for a range of national average prices of between 25·0 and 46·5 cents per lb, by assuming that each farmer's wool price changed from the 1970–1 price by the same proportion as the national average price.

TABLE 3

Percentage Of Farms On Which Mixed Sheep And Cattle Grazing Would Be More Profitable Than Grazing Cattle Alone At Varying Wool Prices

Price (c/lb)	HIGH RAINFALL ZONE						WHEAT AND SHEEP ZONE						PASTORAL ZONE					
	25·0	29·57	34·0	43·00	46·5	Base year price*	25·0	29·57	34·0	43·0	46·5	Base year price*	25·0	29·57	34·0	43·00	46·5	Base year price*
Size of farm (sheep)	%	%	%	%	%	cents	%	%	%	%	%	cents	%	%	%	%	%	cents
1963–4—																		
200–500	14·3	14·3	28·6	57·1	71·4	85·7	30·0	30·0	50·0	70·0	70·0	90·0	..	..	..	..	..	..
500–1,000	2·5	5·0	12·5	35·0	42·5	67·5	29·0	32·3	51·6	61·3	61·3	67·7	0	0	0	0	0	50·0
1,000–2,000	8·1	14·5	25·8	35·5	45·2	75·8	14·0	23·3	32·6	44·2	53·5	76·7	11·1	22·2	22·2	44·4	55·6	77·8
2,000–5,000	3·6	7·3	27·3	38·2	54·5	81·8	10·4	14·6	20·8	43·8	47·9	58·3	16·7	16·7	25·0	50·0	50·0	62·5
5,000–10,000	0	4·5	13·6	31·8	45·5	81·8	0	0	14·3	14·3	28·6	71·4	23·3	26·7	40·0	46·7	46·7	60·0
10,000–20,000	9·1	18·2	18·2	36·4	36·5	63·6	0	0	0	40·0	40·0	80·0	14·3	19·0	23·8	33·3	42·9	52·4
20,000+	..	..	..	..	..	..	..	..	..	..	..	..	18·2	18·2	18·2	36·4	45·5	63·6
1964–5—																		
200–500	20·0	33·3	46·7	66·7	66·7	66·7	20·0	20·0	80·0	80·0	80·0	80·0	..	..	..	..	..	..
500–1,000	8·3	11·1	19·4	55·6	61·1	61·1	12·9	19·4	25·8	48·4	61·3	61·3	0	50·0	100·0	100·0	100·0	100·0
1,000–2,000	10·0	16·7	45·0	61·7	63·3	63·3	8·0	8·0	24·0	36·0	42·0	42·0	10·0	10·0	20·0	30·0	50·0	50·0
2,000–5,000	12·3	10·3	31·6	42·1	43·9	43·9	14·0	16·3	32·6	51·2	58·1	58·1	18·5	22·2	22·2	44·4	44·4	44·4
5,000–10,000	15·0	20·0	30·0	45·0	50·0	50·0	0	14·3	28·6	42·9	42·9	42·9	22·6	22·6	35·5	35·5	48·4	48·4
10,000–20,000	18·2	27·3	36·4	54·5	54·5	54·5	20·0	20·0	20·0	40·0	60·0	60·0	23·8	33·3	33·3	47·6	47·6	47·6
20,000+	..	..	..	..	..	..	..	..	..	..	..	..	53·8	53·8	53·8	61·5	69·2	69·2
1965–6—																		
200–500	13·3	13·3	40·0	60·0	80·0	80·0	27·3	45·5	63·6	90·0	90·0	90·0	..	..	..	..	..	..
500–1,000	7·1	7·1	19·0	45·2	47·6	57·1	11·8	23·5	29·4	47·1	55·9	58·8	0	0	0	100·0	100·0	100·0
1,000–2,000	9·7	17·7	27·4	53·2	59·7	69·4	17·6	19·6	31·4	41·2	45·1	51·0	9·1	18·2	36·4	54·5	54·5	63·6
2,000–5,000	3·4	5·2	20·7	41·4	56·9	65·5	8·2	12·2	26·5	44·9	57·1	63·3	10·7	17·9	32·1	39·3	46·4	64·3
5,000–10,000	4·5	13·6	22·7	50·0	50·0	50·0	0	0	0	28·6	42·9	57·1	23·5	23·5	32·4	44·1	47·1	55·9
10,000–20,000	0	0	18·2	54·5	63·6	72·7	0	0	0	40·0	60·0	60·0	8·3	12·5	20·8	33·3	41·7	41·7
20,000+	..	..	..	..	..	..	..	..	..	..	..	..	23·1	30·8	38·5	46·2	61·5	61·5

* Average price received.

The total wool produced in each size stratum can be calculated from the BAE sample in any particular year of survey. The average wool produced per farm in each stratum in each zone in each state in the BAE sample is calculated first. If this is multiplied by the actual number of farms in the stratum in each zone for each state the total wool production for each stratum is obtained.

This procedure is summarized in the following formula:

(5) $W_i = A_i N_i.$

Where:

W_i = the estimated total quantity of wool produced by the farm size stratum of each state in the base year,

A_i = the average wool produced per farm in stratum (i) of the BAE survey, and

N_i = the total number of farms in stratum (i) in the particular grazing zone of the state.

The wool production from each farm size stratum in each zone can then be summed to obtain an estimate of the total quantity of wool produced in each state. The results of this calculation for the 3 years 1963–4 to 1965–6 are shown in table 4.

The quantity of wool which would be produced by any farm size stratum at a price which is lower than that prevailing in the base year can be estimated if it is assumed that the decline in wool production in the stratum will be proportional to the decline in the number of farms which find mixed sheep and cattle grazing more profitable than grazing cattle alone. The procedure is summarized in equation (6).

(6) $W_p = X_i/100\ W_i.$

Where:

W_p = the quantity of wool produced by the farm size stratum at a price lower than that prevailing in the base year,

W_i = the estimated total quantity of wool produced by the farm size stratum of each state in the base year (as calculated in equation (5), and

X = the percentage of farms changing from mixed sheep and cattle grazing to cattle grazing alone (as calculated in equation (4)).

By using equation (6) at a number of price levels and by summing the quantity of wool produced in each stratum of each zone the total supply of wool in Australia at a number of different prices can be estimated. As the estimated number of farms remaining in mixed sheep and cattle grazing at any particular price varies with each year of the survey, so the estimated supply of wool produced at any particular price will vary with the survey year selected as a base.

TABLE 4

Wool Production as Estimated from the Bureau of Agricultural Economics Survey and Actual Wool Production, 1963–4 *to* 1965–6

	1963–4			1964–5			1965–6		
	Estimated wool production	Actual wool production	Estimated as percentage of actual wool production	Estimated wool production	Actual wool production	Estimated as percentage of actual wool production	Estimated wool production	Actual wool production	Estimated as percentage of actual wool production
	million lb	million lb	%	million lb	million lb	%	million lb	million lb	%
N.S.W. ..	820	678	121	643	655	98	731	533	137
Vic. ..	334	281	119	333	306	109	332	307	108
Qld ..	204	223	91	152	214	71	178	160	111
S.A. ..	172	195	88	176	200	88	172	213	81
W.A. ..	200	207	97	227	198	115	196	235	83
Tas. ..	34	30	113	35	36	97	34	37	92
Aust. ..	1,764	1,614	109	1,566	1,609	97	1,643	1,485	111

The above method of calculating the supply of wool suffers from several major defects. First, it assumes that farmers will act rationally and change from sheep to cattle if the latter are more profitable. Second, it assumes that beef is the only alternative to wool production, while there are a variety of other products which farmers might produce. This latter problem was overcome by Gruen [6] in an earlier estimate of the elasticity of the supply of wool by calculating the elasticity of transformation between wool and a number of possible alternative products. However, there are reasons for supposing that the error introduced by assuming that cattle grazing is the only possible alternative to wool production might not be very great. The Pastoral Zone is too dry for cropping and much of the High Rainfall Sheep Zone is too steep for cultivation and too wet for wheat. The markets for other crops which might be produced are extremely limited. In the Wheat and Sheep Zone other crops could be grown on much of the land which is used for grazing at present. However, in the years immediately preceding the decline in wool prices, wheat was more profitable than wool production and in many areas wheat had already reached the limit of cultivation. In most of the wheat belt a pasture phase is needed to restore soil fertility after cropping, and the area of pasture was probably the minimum needed for this purpose in the mid 1960's when wheat production was expanded to offset declining returns from wool production. Thus, even in the wheat belt it is likely that there will be a direct substitution of cattle for sheep on grazing land if higher profits can be obtained from beef cattle.

An additional problem arises because not all of the farms in the BAE sample grazed more than five cattle. Thus it is necessary to calculate the proportion of farms producing wool at any particular price from the total farms grazing more than five cattle rather than from all farms in the BAE sample. Although the quantity of wool produced at any one price in any farm size stratum is estimated from the average wool per farm in that stratum in the whole BAE sample, it is still possible that the proportion of farms on which sheep grazing would be more profitable than cattle grazing would have been different if all farms in the sample had grazed more than 5 head of cattle. It is also assumed that an accurate assessment of the total wool produced in Australia can be made from the BAE sample by multiplying the average wool production in each farm size stratum in each grazing zone by the actual number of farms in that zone and summing the estimated quantities found for each zone in each state. The error due to this assumption can be examined by comparing the quantity of wool which would have been produced in each of the years in 1963–4, 1964–5, and 1965–6 as estimated from the BAE survey with actual quantity of wool produced in each state. The results of this calculation for each of the survey years 1963–4 to 1965–6 are shown in table 4. The calculated amount differs from the actual amount produced by as much as 37 per cent in some states and by as much as 11 per cent for Australia as a whole.

The most serious fault with the method of estimation however, arose from the discovery that a number of the farms in the survey producing wool in the years 1963–4 to 1965–6 would have been operating more profitably if they had been producing cattle in these years. This discrepancy could be due to the formula used in estimating the relative profitability of beef and sheep failing to accurately describe the true costs and returns from the two enterprises. It could also be caused by farmers remaining in sheep because they did not realize cattle were more profitable or because they lacked the necessary capital to make the change, or as a means of avoiding risk or for any combination of these reasons.

The effect of some of these weaknesses on the price elasticity of the supply of wool can be investigated by calculating the supply of wool at a series of prices on a number of different bases as follows:

(7) $W_n = \Sigma A_i N_i \, E_i / D_i.$

(8) $W_n = \Sigma A_i N_i \, E_i / D_i \, R.$

(9) $W_n = \Sigma A_i N_i \, E_i / Z_i.$

(10) $W_n = \Sigma A_i N_i \, E_i / Z_i \, R.$

Where:

W_n = the estimated total quantity of wool produced at a national average price of P_n,

A_i = the average quantity of wool produced per farm in stratum i in the BAE survey,

N_i = the total number of farms in stratum (i),

E_i = the number of farms in a particular stratum (i), grazing sheep and more than five head of cattle in the base year, whose profits would increase if cattle alone were grazed at the farm wool price P_f which would exist with a national average wool price of P_n,

D_i = the number of farms in stratum i of the BAE survey which grazed sheep and more than five head of cattle in the base year,

Z_i = the number of farms in stratum i of the BAE survey grazing sheep and more than five head of cattle in the base year whose profits were higher than if cattle alone had been grazed, and

R = the ratio between the actual quantity of wool produced in each state in Australia in the base year and the estimated quantity of wool produced in that year as estimated from the BAE survey.

Formulas (7) and (8) assume that in the long term farmers who were still producing wool in the base year, although it would be more profitable to graze cattle alone, would change to grazing cattle alone in the long term. Formula (8) differs from formula (7) by adjusting the wool produced at each price level as estimated from the BAE survey in the base year to the actual quantity produced in that year, by assuming that the discrepancy which existed between the estimated quantity and actual quantity of wool produced will be the same at lower prices as in the base year.

Formula (9) assumes that the same proportion of farmers who produced wool although cattle were more profitable in the years 1963–5 to 1965–6 will continue to do so in the long term when wool prices are lower than in the base year. Formula (10) differs from Formula (9) by adjusting the quantity of wool produced at each price level as estimated from the BAE survey in the base year to the actual quantity produced in that year, by assuming that the discrepancy which existed between the estimated and the actual quantity of wool produced will be the same at lower prices as in the base year. The actual supply of wool was calculated from the number of farms remaining in wool production at a series of national average prices ranging from 25·0 to 46·5 cents per lb, using formulas (7), (8), (9), and (10).

An estimate of the price elasticity of wool supply was obtained from equation (11).

(11) $\log P_n = a + b \log W_n$.

Where:

P_n = the national average price of wool, and

W_n = the quantity of wool produced.

The values of a and b for formulas (7), (8), (9), and (10) for each of the base years 1963–4, 1964–5, and 1965–6 using the range of prices between 25·0 and 46·5 cents per lb shown in table 3, together with the square of the correlation coefficient, are shown in table 5. The long term elasticity of supply is equal to the reciprocal of the regression coefficient and is shown in table 6 for each of the four methods of calculation. The variation in elasticity caused by making different assumptions concerning the number of farms which would or would not remain in sheep is much less than the variation caused by differences in the years on which the calculation is based. Within any one year the maximum variation in elasticity caused by the assumptions adopted varies between 0·04 and 0·09. The maximum variation in elasticity between years using any one method ranges between 0·66 and 0·79.

TABLE 5

The Relationship Between Wool Supply and the Price of Wool

($\log P_n = a + b \log W$)

Basic year of calculation	1963–4	1964–5	1965–6
R^2—			
Formula (7)	0·95	0·93	0·99
Formula (8)	0·93	0·93	0·99
Formula (9)	0·95	0·92	0·99
Formula (10)	0·96	0·93	0·99
INTERCEPT (*a*) CENTS PER LB—			
Formula (7)	—3·2837	—3·4205	—2·0064
Formula (8)	—3·1819	—3·5900	—1·9026
Formula (9)	—3·3990	—3·4208	—2·0419
Formula (10)	—3·4582	—3·6226	—1·9348
REGRESSION COEFFICIENT (*b*)*—			
Formula (7)	0·5579 (0·0739)	0·5734 (0·0908)	0·4112 (0·0239)
Formula (8)	0·5484 (0·0869)	0·5917 (0·0937)	0·4021 (0·0233)
Formula (9)	0·5610 (0·0743)	0·5563 (0·0947)	0·4057 (0·0235)
Formula (10)	0·5703 (0·0672)	0·5776 (0·0915)	0·3959 (0·0230)

* Standard error in brackets.

TABLE 6

The Price Elasticity of the Supply of Wool

Base year	1963–4	1964–5	1965–6
METHOD OF CALCULATION—			
Formula (7)	1·7924	1·7440	2·4319
Formula (8)	1·8235	1·6900	2·4869
Formula (9)	1·7825	1·7976	2·4646
Formula (10)	1·7535	1·7313	2·5259

The range in elasticities over both assumptions and years is between 1·69 and 2·52. This is lower than the long term elasticity of supply of 3·59 calculated by Gruen [6] in 1967 using a six sector model which considered the cross elasticities between wool and five other commodities in which the price of wool and wheat were the major determinants for wool supply. However, it is higher than the estimate of 1·1 made by the BAE [3] based on relationship between past changes in the supply of wool and the price of wool, the price of wheat and the area of improved pasture in Australia. As the calculation in this work assumes that the supply of wool is determined by the relative prices of wool and cattle, it is surprising that the discrepancy between it and the previous estimates is not larger. Gruen [6] found that there was no relationship between the relative prices of wool and beef and the elasticity of the supply of wool. However in the years covered by his investigation the ratio between wool and beef prices was much higher than those anticipated in this study.

The actual quantity of wool which might be produced if any particular wool price persists over a long period of time can be assessed from the price elasticity of supply. The average price for wool during the 3 years 1963–4 to 1965–6 was 51·77 cents per pound, while the average production was 1,744 million pounds. The actual quantity of wool which would be produced at particular prices assuming an elasticity of 1·69 or 2·52 and the percentage this forms of wool production during the base period 1963–4 to 1965–6 are shown in table 7. If a wool price of 40 cents is maintained in the future the wool clip would decline by more than 35 per cent assuming a low long term elasticity of supply of 1·69. Production at 40 cents would fall by more than 50 per cent if the high price elasticity of supply of 2·52 is used. If the long term price is 35 cents per pound, wool production would be reduced by over 50 per cent with an elasticity of 1·69 and by over 80 per cent with an elasticity of 2·52.

TABLE 7

Projected Wool Production at Various Wool Prices and Price Elasticities

Wool price (cents per lb)	Percentage price decline over base years*	Estimated percentage decline in wool production with a price elasticity of		Estimated wool production with an elasticity of	
		1·69	2·52	1·69	2·52
c	%	%	%	m. lb	m. lb
51·77	0	0	0	1744	1744
40·00	22·7	38·36	57·20	1075	748
35·00	32·4	54·76	81·65	789	320
30·00	42·1	71·17	106·09	503	Nil
25·00	51·7	87·37	130·28	220	Nil

* Average of years 1963–4 to 1965–6.

THE LONG TERM SUPPLY OF BEEF AT LOW WOOL PRICES AND CONSTANT BEEF PRICES

If future wool prices are less than 40 cents, a large decline in wool production must be expected. This should be matched by an increase in beef production providing existing cattle prices are maintained. The magnitude of the increase in cattle numbers which might be expected at constant cattle prices can be estimated by assuming that sheep numbers will decrease in proportion to wool production and that sheep will be replaced by cattle at a ratio of 8 to 1. The results of these calculations assuming long term price elasticities of 1.69 and 2.52 are shown in table 8. The projected long term increases in cattle numbers represent a substantial gain over the 1972 Australian cattle population of 24·4 millions. Even with a long term wool price of 40 cents and a wool price elasticity of 1·69, cattle numbers would increase by 7·9 million or 32 per cent of the 1972 cattle population. With a wool price elasticity of

2·52 an increase of 11·8 million cattle or 48 per cent of 1972 population might be expected. If the long term price of wool is as low as 35 cents, increases in cattle numbers of 11·3 to 16·8 million might be expected, representing an increase of between 46 and 69 per cent of the 1972 cattle numbers. Because the returns from beef trading are the dominant factor in determining the relative profits from beef or wool, lower increases in cattle numbers must be expected if cattle prices decline as cattle numbers increase.

TABLE 8

Estimated Decrease in Sheep Numbers and Increase in Cattle Numbers at Various Wool Prices and Wool Price Elasticities

Wool price (cents per lb)	Estimated percentage decline in sheep numbers* with an elasticity of		Estimated sheep numbers with a price elasticity of		Estimated increase in cattle numbers with a price elasticity of	
	1·69	2·52	1·69	2·52	1·69	2·52
	%	%	m.	m.	m.	m.
51·77	0	0	164·7	164·7	0	0
40·00	38·36	57·20	101·5	70·5	7·90	11·78
35·00	54·76	81·65	74·5	30·02	11·28	16·81
30·00	71·15	100·00	47·5	Nil	14·65	20·58
25·00	87·37	100·00	20·8	Nil	17·99	20·58

* From base years (1963–4 to 1965–6) level.

During the last decade beef cattle numbers in Australia have increased at an average rate of six per cent per annum. At this rate it would take approximately five years for Australia's existing herd of 24·4 million cattle to produce an additional eight million. In 1971–2, 52 per cent of the 1,023,000 tons of beef and veal produced in Australia was exported. In these circumstances increasing Australia's cattle numbers by 32 per cent would increase exports by approximately 61 per cent, while an increase in cattle numbers of 69 per cent would increase beef exports by approximately 133 per cent. During the last decade, Australia's exports of beef and veal have increased by 62 per cent. If the long term price elasticity of a supply for wool is as low as 1·69 and the future average of wool is 40 cents a lb, sheep numbers will decline by 64 millions and cattle numbers will increase by eight millions. Thus, beef exports would need to expand at at least twice the rate they have in the past if the additional cattle produced as a result of beef production being more profitable than wool production are to be sold at existing prices.

The long term price elasticity of wool suggests that Australia's wool production might decline to between one third and one half of its existing level and that cattle numbers might increase by a similar proportion if future wool prices were as low as 30 or 40 cents per lb for a long period of time. However a lack of markets for the additional beef produced could depress cattle prices and cause the change from sheep to cattle to be spread over at least a decade.

APPENDIX 1: ESTIMATION OF THE LABOUR REQUIREMENTS OF SHEEP

Tyler [11, 12] estimated that the variable labour requirement of each sheep carried was 0·12 man days per annum and that each cow and calf required 0·44 man days of labour per annum. As the average calving percentage in southern Australia is approximately 80 per cent and as many calves are sold before they are one year old the average herd would probably consist of one third calves and two third cows. Thus Tyler's figure of 0·44 man days for a cow and calf is the equivalent of 0·30 man days per beast carried. Tyler considered that the total labour requirement for cattle consisted of 0·027 man days per beast for marking and branding and 0·27 man days for other work directly associated with cattle. During the early 1960's, when the BAE Survey was conducted, beef cattle were seldom drenched, weighed or pregnancy tested. In these circumstances it is difficult to accept Tyler's high figure for other work on cattle, particularly as Tyler specifically excluded work on repairing fences and watering points, which might be expected to increase slightly if sheep are replaced by cattle. A more sensible approach is to accept Tyler's figures for sheep and assume that work on cattle is limited to marking and branding. While this underestimates the total work required for cattle it is almost certainly a closer approximation than Tyler's estimation of 0·44 man days per cow*. On this basis, labour would decline by 0·933 (0·12 × 8 — 0·027) may days for each beast replacing 8 sheep equivalents. Assuming a 250 working day year this represents a decline in the labour force of one man when 2,144 sheep equivalents are replaced by 268 cattle.

In practice an underestimation of the labour requirements of cattle will have little effect on the estimation of the relative profitability of sheep and cattle as savings due to a reduction in labour force are limited to large properties. Permanent labour can only be removed in whole man units and sheep numbers must decline by 2,144 before one labour unit is removed. The percentage of Australian sheep properties carrying 2,000 to 5,000 sheep and more than 5,000 sheep in the different grazing regions are as follows:

	2,000 to 5,000 sheep	Over 5,000 sheep
	%	%
Pastoral Zone	40	40
Wheat and Sheep Zone	15	1
High Rainfall Sheep Zone ..	15	2

A change from sheep to cattle would only have a major effect on labour costs in the Pastoral Zone. Labour saving on most properties in the High Rainfall and Wheat and Sheep Zones would be limited to the elimination of the small amount of casual labour employed.

* A study of the time required for livestock operations which is being carried out on the Southern Tablelands at the present time suggests that the total labour required for cattle is approximately 0·12 hours per beast, although pregnancy testing and weighing, operations which were not performed in the mid-1960's, are now carried out on many properties.

REFERENCES

[1] BENNETT, D., F. H. W. MORLEY, K. W. CLARK, and M. L. DUDZINSKI, "The Effect of Grazing Cattle and Sheep Together", *Australian Journal of Experimental Agriculture and Animal Husbandry*, Vol. 10, p. 694 (1970).

[2] BUREAU OF AGRICULTURAL ECONOMICS, *The Australian Sheep Industry Survey* 1963–4 (Canberra, 1967). *The Australian Sheep Industry Survey*, 1964–5 *to* 1966–7 (Canberra, 1969).

[3] BUREAU OF AGRICULTURAL ECONOMICS, *A Study of the Supply Relationship in the Australian Sheep and Wool Industry* (Canberra: 1971) pp. 76–80.

[4] CULPIN, S., W. M. R. EVANS, and R. L. FRANCIS, "An Experiment on Mixed Stocking of Pasture", *Experimental Husbandry*, Vol. 10 (1964), p. 29.

[5] EBERSOHN, J. P., "Effects of Stocking Rate, Grazing Method and Ratio of Sheep and Cattle on Animal Liveweight Gains in a Semi-Arid Environment", *Proceedings of the Tenth International Grasslands Conference*, Helsinki (1966), p. 495.

[6] GRUEN, F. H., *Long Term Agricultural Supply and Demand Projections Australia* 1965 *to* 1980 (Department of Economics, Monash University, Clayton, Australia 1967). pp. 6–36 to 6–38.

[7] HAMILTON, D. and J. G. BATH, "Performance of Sheep and Cattle Grazed Separately and Together", *Australian Journal of Experimental Agriculture and Animal Husbandry*, Vol. 10 (1970), p. 19.

[8] PEART, J. N., "Increased Production from Hill Pastures; Sourhope Trials with Cattle and Sheep", *Scottish Agriculture*, (1962–3), p. 1.

[9] SNELL, M. G., "Pasture Gains of Cattle, Cattle and Sheep and Sheep", *Proceedings of the Annual Meeting of the American Society of Animal Production*, Vol. 27 (1962), p. 142.

[10] TYLER, G. J., "Labour Requirements on Wheat Farms in the North Western Slope of N.S.W.", *Review of Marketing and Agricultural Economics*, Vol. 31 (1963), pp. 73–99.

[11] TYLER, G. J., "Optimum Programmes for Wheat Farms in the North Western Slopes", *Review of Marketing and Agricultural Economics*, Vol. 32 (1964), pp. 5–35.

[12] WARD, F. L., "Beef Cattle and Sheep on Hill Country Farms", *Proceedings of the* 24*th New Zealand Grassland Association Meeting*, (1962), p. 95.

[13] WILLS, L. R. and A. G. LLOYD, *Beef Cattle Production in the Western District of Victoria*, (University of Melbourne, 1968).