SUPPLY RESPONSES FOR WOOL IN SOUTH AUSTRALIA, 1949-61*

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This note summarizes some exploratory quantitative estimates of the main influences on variations in wool supply for each of the Sheep Industry Zones of South Australia. As classified by the Bureau of Agricultural Economics, these areas are known as the Wheat-Sheep, High Rainfall, and Pastoral Zones. Characteristics of the zones, and their boundaries, both for South Australia and Australia, are outlined in the *Sheep Industry Survey Reports* of the B.A.E.

The basic method used was least-squares regression with preselected lagged variables. Those lagged variables whose coefficients were not initially significantly different from zero were eliminated and the regression recomputed. This process was continued to find the 'best' supply equation for each zone in terms of the significance of all coefficients, and to a lesser extent, the multiple correlation coefficient R. In addition, Nerlove-type distributed-lag analysis was tried and the unsuccessful results of this endeavour are given towards the end of the note.[1]

Throughout, annual data relating to the period 1945-46 to 1960-61 were used. The data, and comments thereon, are given in an appendix. To conserve degrees of freedom, price ratios rather than simple prices have been used in some equations.

Although greasy wool production has been used as the dependent variable throughout the regressions, this has been equated with supply because graziers usually dispatch their clip immediately after shearing and set no reserve price on its sale.

Wheat-Sheep Zone

The important influences on supply in this zone (X_1) were thought to be the prices of (greasy) wool (P_{wo}), wheat (P_{wh}), fat lambs (P_f), and barley (P_b), along with changing technology and weather conditions. However, because it was not possible to obtain a suitable indicator of weather conditions, combined with the fact that the major part of technology's influence has been the increasing acreage sown to improved pasture (Z_1), it was decided to run Z_1 as the only non-price variable. Strictly, in terms of pasture effects *per se*, Z_1 should be lagged. But because the *area* of improved pasture is influenced itself by weather conditions,[2] it was decided not to lag it. Furthermore, because the rate of increase of

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[1] Full details of the analysis are presented in Dahlberg, D. L., *Econometric Analysis of South Australian Post-war Wool Supply*. B.Ec. Hons. thesis, University of Adelaide, 1963.

[2] There were interruptions to the steady trend in this variable in the two drought years 1957/58 and 1959/60.

improved pasture has been reasonably uniform, to avoid multicollinearity it was decided to let all technology effects be carried by Z_1 rather than include time, the conventional surrogate.[3]

Initially, the price ratios P_{wo}/P_{wh} and P_{wo}/P_f, both lagged one, two and three years, were included in the analysis, as shown in regression (1) of Table 1. Because barley (which is a substitute for wheat in the coastal areas) was thought to be less important, a P_{wo}/P_b ratio was not introduced until later.

Successive regressions, also shown in Table 1, eliminated the lagged price ratios for those terms with the smallest and least significant coefficients. Regression (6) appears to be the best of these six regressions, being preferable to (5) because of the greater significance of all its coefficients. Indeed, the coefficients for (6) are all significant at the 5 per cent level and two of the four coefficients are significant at the 1 per cent level. Since regression (6) indicated only a one year lag for P_{wo}/P_{wh}, it was decided to introduce P_{wo}/P_b with a one year lag. As regression (7) shows, this change lead to no improvement.

The coefficients obtained in (6) give supply elasticities of —0·47 and 0·13 for P_{wo}/P_f lagged one year and two years respectively[4]. For P_{wo}/P_{wh} the appropriate elasticity is 0·42. These estimates imply that if the level of wheat and fat lamb prices were constant, and the area of improved pasture remained unchanged, a 1 per cent change in greasy wool prices would result in a change of —0·05 per cent (i.e. 0·42—0·47) in wool supply in the first year succeeding the change, and an overall change of 0·08 per cent (i.e. —0·05 + 0·13) over the two years following the wool price change. That is, the estimates imply a 'short-run' elasticity of supply for wool of —0·05 and a 'long-run' elasticity of 0·08.

The coefficient for the area of improved pasture corresponds to an elasticity of 0·08. More simply, it implies that an extra 8·4 lb of wool is produced for each additional acre of pasture improved, corresponding to a stocking rate increase of about one sheep per acre. This value perhaps understates the actual increase in wool production when an acre of pasture is sown because the data makes no adjustment for newly established pasture not yet operating at capacity, nor for the fact that stock other than sheep utilize some improved pasture. On the other hand, to the extent that the pasture variable is a surrogate for the effect upon wool production of other technological changes, this tendency to understate may be counteracted.

The cross elasticity of wool with respect to wheat of —0·42 provides an estimate of the upper limit to the short-run elasticity of supply of wool. The substitution of a grain crop for sheep (and vice versa) would be the easiest substitution available to a wheat-zone grazier—providing, of course, he is not operating his grain machinery to capacity. This is because he typically follows a flexible rotation scheme between grain area and pasture,[5] and can buy or sell a portion of his flock in the market place fairly quickly.

[3] The correlation between time and Z_1 was 0·94.

[4] All elasticities have been calculated at the mean levels of the variables.

[5] The normal system of ley farming is to use a rotation system with pasture for 6 years followed by two years cropping. The flexibility comes about by reducing or increasing the pasture time and by choosing whether to crop for 1, 2 or 3 years.

TABLE 1

Regressions on S.A. Wheat-sheep Zone Wool Production

Regression Number	P_{wo}/P_{wh}			P_{wo}/P_f			P_{wo}/P_b	Z_1	R^2
	$t-1$	$t-2$	$t-3$	$t-1$	$t-2$	$t-3$	$t-1$		
(1)	243 (118)	—62·8 (184)	—47·3 (178)	—390 (191)	157 (280)	64·7 (243)		10·5 (5·7)	0·99
(2)	258** (95)	89·6 (141)	0·6 (30)	—406* (166)	207 (191)			9·7* (4·5)	0·91
(3)	257** (96)	—89·3 (142)		—405* (168)	206 (194)	1·3 (40)		9·8* (4·5)	0·91
(4)	258** (86)	—89·7 (131)		—406** (151)	207 (177)			9·7** (4·2)	0·91
(5)	192** (67)	59·8* (29)		—274** (103)				7·2* (3·6)	0·89
(6)	216*** (59)			—324*** (91)	88·9** (37)			8·4** (3·6)	0·90
(7)	178** (75)			—357** (101)	96 (39)		44 (53)	7·2* (3·9)	0·91

Note: * denotes significance at the 10 per cent level, ** at the 5 per cent level, and *** at the 1 per cent level. Standard errors are given in parentheses.

The values for the cross elasticity of supply of wool with respect to fat lamb price, 0·47 in the first year and —0·13 in the second year, undoubtedly raise some questions. For a start, the result is quite different from that obtained for New Zealand farms by Rowe[6]. Relating the number of sheep shorn to the lamb/wool and lamb/mutton price ratios, he found a cross elasticity of —0·24 over two years as compared to the South Australian estimate of 0·34 (i.e. 0·47 — 0·13) over two years. However, the structure of the New Zealand sheep industry, producing fat lambs on well-watered pastures, is quite different from that in the South Australian wheat-sheep zone.

By what possible mechanism could a 1 per cent rise in wool prices relative to fat lamb prices (due to a fall in fat lamb prices) cause wool production in the following year to fall by 0·47 per cent but subsequently increase by 0·13 per cent in the next year? If the estimates are in fact correct, the only appealing explanation would seem to be that in response to relatively higher wool prices, sheep tend to move out of the wheat-sheep zone in the immediate short run so as to substitute for marginal fat lamb production outside the zone. The second year response is not in conflict with this possibility. But as regional data is not available on sheep migration, such an hypothesis could not be investigated. Obviously, however, the lamb price response (if true) is one which occurs on most properties and not just fat lamb properties. If the response occurred only on fat lamb properties, which comprise approximately 20 per cent of sheep farms in the zone, then the size of the adjustment for individual farms would be outlandish.

High Rainfall Zone

The variables studied for this zone were a ratio of wool prices to the prices of all products excluding wool (P_{ap}), and the acreage of improved pasture (Z_2); the latter variable again being unlagged. However, the time trend in both wool production (X_2) and the area of improved pasture was so strong that no price influence could be detected.[7] The results of the three regressions computed, (8) to (10), are shown in

TABLE 2

Regressions on S.A. High Rainfall Zone Wool Production

Regression number	$(P_{wo}/P_{ap})_{t-1}$	$(P_{wo}/P_{ap})_{t-2}$	$(P_{wo}/P_{ap})_{t-3}$	Z_2	R^2
(8)	—19·5 (51)	13·3 (47)	—63·2 (43)	18·2*** (2·6)	0·91
(9)	—32·3 (52)	—13·9 (45)		17·1*** (2·6)	0·89
(10)	—36·4 (48)			17·2*** (2·5)	0·88

Table 2. While the degree of trend in both wool production and pasture improvement remains as high as it is, it is unlikely that any direct estimate of the own-price elasticity of supply of wool in the high rainfall zone can be made using time-series techniques.

[6] Rowe, J. W. Economic Influences on Livestock Numbers in New Zealand, 1920-1950. *J. Farm Econ.* 38: 860-863, 1956.

[7] The correlation of X_2 with time was 0·99; with Z_2 it was 0·95.

Although the price coefficient is unsatisfactory, being of the wrong sign as well as non-significant, the pasture improvement coefficient is highly significant. For regression (10), the pasture improvement coefficient implies an extra 17·2 lb. of wool for each extra acre of improved pasture, or equivalently, an increase in stocking rate of about 2 sheep per acre. Given as an elasticity it is 0·61. However similar qualifications to those expressed for the wheat-sheep zone pasture variable also apply here.

Pastoral Zone

Although the main influences upon wool production in this zone (X_3) were thought to be the price of wool, changing technology, and weather (both for the year in question and for previous years in so far as it affects previous years' stock levels), it was only possible to incorporate the price of wool. A time-trend variable, (T), was also included. The three regressions calculated, (11) to (13), are shown in Table 3. The

TABLE 3

Regressions on S.A. Pastoral Zone Wool Production

Regression number	$P_{wo,\ t-1}$	$P_{wo,\ t-2}$	$P_{wo,\ t-3}$	T	R^2
(11)	1·18 (40)	36·9 (35)	15·2 (30)	1,122** (407)	0·60
(12)	3·07 (38)	44·0 (31)		1,138** (391)	0·59
(13)	11·20 (39)			980** (391)	0·51

analysis failed to indicate any short-run price influence in this zone, only the time variable being significant. This is reasonable considering that most short-run decisions in this area would be largely on the basis of the natural feed available. As already noted, there is a strong time trend evident in the regressions. However, it would be wrong to assume this indicates advances in technology because, for the ten years following the 1944-46 drought, there was continuous restocking to the pre-drought level.

The low values of R^2 for regressions (11) to (13) indicate that significant influences upon wool supply fluctuations have not been included in the regressions. Knowing that weather is by far the greatest of these, one may make a very tentative estimate that weather influences are responsible for something of the order of 30 to 40 per cent of changes in wool supply in the South Australian pastoral zone.

Distributed-lag Analysis

Nerlove has elaborated a method for estimating long-run elasticities by assuming lags are distributed such that the effects of past changes decline at a geometric rate.[8] He assumes two influences. The first is that there is some expected price P^* which is a function of past prices such that

[8] Nerlove, M. *The Dynamics of Supply: Estimation of Farmers' Response to Price.* Johns Hopkins Press, Baltimore, 1958, pp. 54-5.

(I) $P^*_t = P_{t-1} + (1-\beta)P_{t-2} + (1-\beta)^2 P_{t-3} \ldots + (1-\beta)^{n+1} P_{t-n}$

where β is called the coefficient of expectations and is restricted to values between 0 and 1.

Secondly, Nerlove postulated an equilibrium output x^* for each particular P^*, the supply adjustment process being for farmers to alter their output by a proportion γ of the difference between last year's equilibrium output, x^*_{t-1}, and last year's actual output, x_{t-1}. That is,

(II) $x_t - x_{t-1} = \gamma(x_{t-1} - x^*_{t-1})$

where γ is termed the coefficient of adjustment and is also restricted to values between 0 and 1.

If one assumes the simple supply relation

(III) $x^*_t = a_0 + a_1 P^*_t + U_t$

where U_t is an error term, then by removing unobservables from equations I, II and III one obtains

$$x_t = a_0 + a_1 \beta\gamma P_{t-1} + [(1-\beta) + (1-\gamma)] x_{t-1} - (1-\beta)(1-\gamma) x_{t-2} + \gamma[U_t - (1-\beta) U_{t-1}]$$

given appropriate initial conditions. This implies a regression of the form

$$x_t = A + BP_{t-1} + Cx_{t-1} + Dx_{t-2}$$

where, because of the constraints on β and γ, there will be constraints for B, C and D such that $0 \leqq B \leqq 1$, $0 \leqq C \leqq 2$ and $-1 \leqq D \leqq 0$. Such regressions were run for the three zones with the ratio of wool prices (P_{wo}) to prices paid by farmers (P_c) as the price variable. In no case were the requirements of the model met. The three regressions are given in Table 4. The lack of success was probably due to the effects of multicollinearity, the omission of a weather variable, and the omission of stock inventory effects.

TABLE 4

Distributed-lag Regressions

Wheat-sheep zone ($R^2 = 0{\cdot}81$)

(14) $X_{1,t} = \underset{}{21{,}270} + \underset{(14)}{19{\cdot}9} (P_{wo}/P_c)_{t-1} + \underset{(0\cdot26)}{0{\cdot}42} X_{1,t-1} + \underset{(0\cdot25)}{0{\cdot}36} X_{1,t-2}$

High rainfall zone ($R^2 = 0{\cdot}96$)

(15) $X_{2,t} = 2{,}809 - \underset{(26)}{8{\cdot}7} (P_{wo}/P_c)_{t-1} + \underset{(0\cdot30)}{0{\cdot}39} X_{2,t-1} + \underset{(0\cdot30)}{0{\cdot}66} X_{2,t-2}$

Pastoral zone ($R^2 = 0{\cdot}44$)

(16) $X_{3,t} = 17{,}166 - \underset{(28)}{23{\cdot}2} (P_{wo}/P_c)_{t-1} + \underset{(0\cdot33)}{0{\cdot}20} X_{3,t-1} + \underset{(0\cdot24)}{0{\cdot}29} X_{3,t-2}$

Conclusion

Albeit tentatively, results presented here suggest that wool supply up to three years beyond price change is quite unresponsive to wool price changes *per se* in the pastoral and high rainfall zones of South Australia. In the wheat-sheep zone, wool appears to have a low own-price elasticity of supply of about $+0{\cdot}1$ over the two years following a price change.

It was not possible to derive an estimate of the longer-run elasticity of supply of wool from either the Nerlove-type model or the estimation technique where no *a priori* lag distribution was assumed. Such an elasticity estimate would perhaps be of more value to the policy maker than the short-run estimate. In such a context, however, account would have to be taken of the fact that pasture improvement has been the major vehicle through which wool supply has expanded in the post-war period. Because the rate of pasture improvement is undoubtedly itself a function of wool prices and total farm incomes, wool price effects would have to be removed from this pasture variable.

Although pertaining directly only to the South Australian sheep zones, to the extent that these zones are not extremely atypical of those in other states, the results presented above might also be regarded as providing some pointers to the overall Australian wool-supply scene. Certainly, they give an indication of the likely problems involved in developing more thorough investigation of wool supply phenomena.

APPENDIX: *Data Used*

Year	X_1	X_2	X_3	P_{wo}	P_{wh}	P_f	P_b	P_c	P_{ap}	Z_1	Z_2	T
	South Australian Wool Production			B.A.E. index of wool prices received by farmers	B.A.E. index of wheat prices received by farmers	Index of South Aust. lamb prices	Index of South Aust. barley price	B.A.E. index of prices paid by farmers	B.A.E. index of prices received by farmers for all products excluding wool	*South Australian Improved Pasture*		
	Wheat-sheep zone	High rainfall zone	Pastoral zone							Wheat-sheep zone	High rainfall zone	Time
	'000 lb. greasy	'000 lb. greasy	'000 lb. greasy	1945–50 = 100						'000 acres	'000 acres	
1945–46	39,946	19,313	3,788	41	62	83	62	85	78	41	326	1
1946–47	38,629	22,514	38,629	64	81	92	88	87	86	38	420	2
1947–48	45,870	24,091	45,870	103	114	100	166	95	104	81	487	3
1948–49	48,856	25,047	48,856	126	125	106	82	106	112	72	647	4
1949–50	56,914	29,268	56,914	167	119	120	102	117	123	124	704	5
1950–51	60,237	27,684	60,237	377	128	162	106	139	146	160	770	6
1951–52	66,522	33,713	66,522	192	135	170	160	175	179	170	858	7
1952–53	79,257	36,088	79,257	216	147	186	159	188	178	440	1215	8
1953–54	68,132	35,548	68,132	212	136	220	100	191	181	594	1583	9
1954–55	75,974	43,143	75,974	186	122	227	134	192	174	772	1857	10
1955–56	82,727	46,412	82,727	159	122	210	104	199	183	693	1904	11
1956–57	87,849	53,785	87,849	207	125	203	107	209	184	1508	2423	12
1957–58	83,235	55,364	83,235	164	129	201	117	215	181	1485	2508	13
1958–59	80,577	56,613	80,577	127	134	183	110	214	183	1735	2136	14
1959–60	86,146	60,868	86,146	151	136	170	99	219	191	1294	1963	15
1960–61	75,048	59,674	75,048	132	135	201	90	226	200	1645	2393	16

Notes:

1. Where ratios of price indices have been used, they have been multiplied by 100 to bring them back to a base of 100 as ratios.
2. The index of fat lamb prices has been constructed from the average price per pound (dressed weight) for 1st and 2nd export grade lambs sold at Gepps Cross abattoirs since 1947, as published in the *Annual Report* of the Australian Meat Board. For 1945-46 and 1946-47, estimates were made by adding the differential between the 1947-48 price for this series and the average price of lamb meat exported from South Australia (as given by the South Australian *Statistical Register*) to the values for the two years previous.
3. The index of barley prices is a chained index of the two series that have appeared in the South Australian *Statistical Register*. The present series "Merchants Average Buying Prices" was chained to the former series "Prices at Principal Markets" in 1950-51.
4. There has been a continuous change in the framing of the question dealing with improved pastures in the annual Agricultural, Dairying and Pastoral Returns of the Bureau of Census and Statistics, Adelaide Office. The object has been to obtain a complete coverage of grasses other than native grasses fertilized. This has necessitated changes in the dates when the area was to be counted, as well as differing instructions. When approached, the Bureau was not prepared to give an indication of bias introduced by these changes.