THE EFFECT OF WHEAT ACREAGE SHIFTS UPON THE MEAN AND VARIANCE OF TOTAL YIELDS IN N.S.W.

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Introduction

The responsiveness of wheat acreage to the relative prices of wheat and wool was demonstrated in a recent paper in this journal.[1] That paper concentrated on estimating short and long run price elasticities of supply for wheat in New South Wales.

For the period studied, 1947-48 to 1962-63, there were large movements in total wheat acreages and also in the geographical distribution throughout the state. This paper describes some effects of the changing geographical distribution of wheat production on—

(i) Average yields per acre, and
(ii) Variance of yield of wheat per acre.

Acreage Shifts and Average Yields

A possible consequence of acreage shifts is that expansion (or contraction) into wheat areas of high or low variability will lead to changes in the mean and the variance of state wheat yield per acre. We have set out to examine these changes over the 32-year period from 1930-31 to 1961-62. The data used have been described in the previous paper[2] where they were used to define homogenous aggregates for the supply analysis. Acreages and yields per acre of wheat for grain were collected from New South Wales Statistical Register for 38 areas in the Tablelands, Slopes, Plains and Riverina statistical divisions. We have referred to areas in the tables in this paper by numbers. They are identified in the Appendix.

The means of the series of yields per acre over the 32 year period for each area, given by

$$\overline{Y}_i = \frac{\sum_{t=1}^{32} Y_{it}}{32}$$

are presented in Table 1, together with standard deviations and coeffic-

* This paper is the second report on what is intended to be a continuing programme of research at the University of New England into economic aspects of the wheat industry in Australia. A study similar to that reported here was commenced, but not continued with at the University of Sydney under the direction of Dr. R. M. Parish. We are indebted to Dr. Parish for allowing us to draw upon his earlier work. We are also indebted to Mrs. June Crawford of the Basser Computing Department, University of Sydney, for programming the evaluation of the quadratic form involved in the variance model.

[1] J. H. Duloy and A. S. Watson, "Supply Relationships in the Australian Wheat Industry: New South Wales", *Australian Journal of Agricultural Economics*, Vol. 8, No. 1, pp. 28-45.

[2] J. H. Duloy and A. S. Watson, *op. cit.*, pp. 31-33 and Appendix 1, pp. 41-42.

ients of variation. It will be noticed that there are quite wide differences in the yields and yield variability of the different areas.

TABLE 1

Means, Standard Deviations and Weights for all Areas

Area	$\bar{Y}_i$	S.D.	Coefficient of Variation	W_1 1930-31 to 1932-33	W_2 1940-41 to 1942-43	W_3 1950-51 to 1952-53	W_4 1959-60 to 1961-62
1	12·44	5·43	43·64	10·121	9·065	7·650	6·553
2	16·35	6·13	37·49	2·573	2·999	2·414	2·492
3	15·52	5·83	37·56	3·068	3·115	2·555	2·248
4	16·91	5·82	34·42	1·738	1·714	1·419	1·647
5	16·17	5·56	34·38	2·172	1·428	2·007	1·636
6	18·30	7·74	42·30	2·894	2·128	1·935	2·208
7	18·14	5·05	27·84	2·163	1·265	1·909	1·298
8	15·04	5·68	37·77	3·596	2·853	2·816	2·271
9	17·13	5·19	30·30	3·150	2·560	2·389	2·078
10	17·03	5·59	32·82	2·085	2·008	2·213	1·887
11	16·02	4·69	29·28	3·261	2·539	3·043	2·334
12	10·80	5·70	52·78	6·415	3·057	2·380	3·155
13	15·50	6·09	39·29	2·855	2·219	2·020	1·971
14	13·21	6·57	49·73	3·180	1·331	1·513	2·114
15	14·11	4·88	34·59	5·589	4·997	4·828	4·194
16	15·53	5·96	38·63	2·984	5·201	5·577	5·150
17	14·97	5·22	34·87	0·536	1·230	1·462	2·047
18	15·62	6·41	41·04	0·427	2·445	2·880	3·582
19	14·50	5·14	35·45	1·284	2·796	3·024	2·881
20	13·81	5·87	52·51	2·065	3·581	5·219	5·438
21	16·62	5·47	38·93	0·185	1·309	1·373	3·619
22	12·83	6·29	49·03	0·297	0·437	0·630	2·378
23	16·10	5·33	33·11	2·108	2·706	2·504	1·775
24	14·83	4·98	33·58	1·275	1·690	1·626	1·157
25	16·06	5·35	33·31	1·088	1·985	2·268	1·655
26	14·87	5·71	38·40	5·857	6·233	5·898	5·916
27	15·26	6·57	43·05	2·915	3·364	3·822	4·200
28	12·88	5·22	40·53	2·880	2·955	2·780	3·083
29	14·07	5·11	36·32	1·793	1·920	1·909	1·410
30	13·86	6·20	44·73	3·088	3·141	2·701	2·857
31	14·98	5·40	36·05	2·388	2·643	2·732	1·901
32	17·48	6·10	35·24	2·400	2·397	2·211	1·864
33	10·84	5·92	54·61	6·835	5·980	4·575	5·811
34	18·61	6·31	33·91	1·869	1·810	1·555	1·504
35	15·17	5·15	33·95	2·275	3·025	2·960	1·744
36	15·11	4·85	32·03	0·222	0·332	0·469	0·349
37	16·22	4·50	27·74	0·087	0·051	0·084	0·154
38	14·53	4·94	34·00	0·382	0·491	0·649	1·436

Also presented in Table 1 are the acreages for each area for each of four three-year periods, 1930-31 to 1932-33, 1940-41 to 1942-43, 1950-51 to 1952-53, and 1959-60 to 1961-62 expressed as a percentage of total state acreage over the period. These weights, W_{i1}, W_{i2}, W_{i3} and W_{i4} respectively (and W_{ik} in general) measure the relative importance in total acreage of the various areas. It can be seen that there have been considerable shifts in the relative importance of the areas over the period studied.

Using these weights and the mean yields for the areas ($\overline{Y}_i$) it is possible to calculate the quantities

$$\hat{\overline{Y}}_k = \frac{\sum_{i=1}^{n} \overline{Y}_i \cdot W_{ik}}{100}$$

which measure the effects of acreage shifts upon the state yield per acre. It could be expected that an expansion of wheat production into higher yielding regions would lead to an increase in state average yield. Computed values of $\hat{\overline{Y}}_k$ are presented in Table 2.

TABLE 2

The Effect of Location of Production Upon State Average Yield

Period	$\hat{\overline{Y}}_k$
1930-31 to 1932-33	14·51
1940-41 to 1942-43	14·72
1950-51 to 1952-53	14·83
1959-60 to 1961-62	14·71
1930-31 to 1961-62	14·72

The Variance Model

We define the average yield per acre for the state, in the t-th year, as

$$\overline{Y}_t = \frac{\sum_{i=1}^{n} p_{it}}{\sum_{i=1}^{n} a_{it}} \qquad \ldots\ldots (1)$$

where p_i is the production, and a_i the area, of wheat in the i-th shire.

We define the yield per acre of wehat in the i-th shire in the t-th year as

$$y_{it} = \frac{p_{it}}{a_{it}} \qquad \ldots\ldots (2)$$

Letting $\sum_{i=1}^{n} a_{it} = A_t$, we may rewrite (1) as

$$\overline{Y}_t = \frac{\sum_{i=1}^{n} y_{it}\, a_{it}}{A_t}$$

$$= \Sigma\, y_{it} R_{it} \qquad \ldots\ldots (3)$$

Where $R_{it} = \frac{a_{it}}{A_t}$, and is the proportion of state wheat acreage grown in area i.

If $v_{ii(t)}$ is the variance of y_{it} and $v_{ij(t)}$ is the covariance of y_{it} and y_{jt}, then the variance of state average yield per acre in the t-th year is given by

$$V(\bar{Y}_t) = R_t' V_t R_t$$
$$= (1/A_t^2)\, a_t' V_t a_t \quad \ldots\ldots (4)$$

where V_t is the variance-covariance matrix of shire yields per acre in the t-th year, R_t is a column vector with elements $\frac{a_{it}}{A_t}$, and a_t is a column vector of shire acreages in the t-th year with elements a_{it}.

We seek to determine the effects upon $V(\bar{Y}_t)$ of shifts in wheat acreages, that is, of different values of the vectors a_t. For this reason we abstract from possible changes over time in V_t by assuming $V_t = V$, all t.[3] To indicate this assumption we introduce the notation

$$V_t(\bar{Y}) = (1/A^2) a_t' V a_t \quad \ldots\ldots (5)$$

We estimated V by $\hat{V}$ using observations over the 32 year period; and, using different weights (a_t) computed estimates of the variance

$$\hat{V}_t(\bar{Y}) = (1/A^2) a_t' \hat{V} a_t \quad \ldots\ldots (6)$$

for each year. In table 3 we present computed values of the variance of total production according to

$$\hat{V}_t(P) = a_t' \hat{V} a_t \quad \ldots\ldots (7)$$

together with total acreage, A_t, and $\hat{V}_t(\bar{Y})$ as defined in (6).

Discussion

The extent of acreage shifts in the New South Wales wheat belt can readily be seen in Table 1. There are two broad movements. Firstly, there is a decreasing proportion of wheat grown on the western fringe—these are areas where yields are lower than average, variability higher and the success of wheat growing depends largely on having farms of adequate size. Historically, it was in this region that the low income problem of the wheat industry was most obvious in the 1930's.

The second broad movement is the expansion of wheat growing into northern New South Wales. Yields in this area are somewhat higher than on the western fringe but the variability is comparable.

The hypothesis tested by the variance model, that the variance of average yield per acre has been altered through acreage shifts, is not substantiated by the results, $\hat{V}_t(\bar{Y})$ being nearly constant over the period (see Table 3). This is apparently due to the fact that the broad movements in geographical distribution are compensating as far as variance is concerned, since both marginal western and northern New South

[3] It is of interest to speculate whether this matrix has, in fact, changed over time. We have not carried out any tests on the variances *per se*. However, we can assume that the variances of yields per acre are due mainly to climatic influences, modified by changing cultural practices, and that the variance due to climate is constant. We then have an indirect test. It could be expected that changing cultural practices, varieties and so forth, would affect mean yields over time as well as variances. We regressed yields per acre against time for each of the 38 areas over a 32 year period. In only 4 cases were the regressions significant. Hence, we conclude that it is likely that V_t is constant.

Wales areas have higher variability of yields per acre than average. However, it is interesting to note that the lowest results for $\hat{V}_t(\bar{Y})$ occur from 1948-49 to 1953-54 when the decline in the western fringe areas had commenced but the post-war growth in northern New South Wales was still in its early stages. However, the extent of differences in this period from the average over the 32 year period is inconsequential.

The period when $V_t(\bar{Y})$ was generally highest occurred during the early thirties when wheat acreages were high in the western margin of the wheat belt. However, even during this period, the effects of the location of production upon variance are negligible.

TABLE 3

Estimated Variances of Total Production and Yield Per Acre, New South Wales

Year	$\hat{V}_t(P)$ (10^{12} bushels)	A_t (10^6 acres)	$\hat{V}_t(\bar{Y})$ (bushels)
1930-31	545·85	5·1131	20·88
1931-32	278·18	3·6634	20·73
1932-33	476·14	4·7840	20·80
1933-34	433·07	4·5654	20·78
1934-35	315·25	3·8773	20·97
1935-36	309·10	3·8378	20·99
1936-37	328·75	3·9710	20·85
1937-38	410·32	4·4500	20·72
1938-39	442·40	4·6108	20·81
1939-40	398·89	4·3283	20·81
1940-41	402·00	4·4035	20·73
1941-42	319·04	3·9330	20·63
1942-43	187·57	3·0046	20·77
1943-44	149·42	2·6852	20·72
1944-45	167·00	2·8374	20·74
1945-46	294·85	3·7796	20·64
1946-47	413·92	4·4564	20·84
1947-48	526·76	5·0271	20·84
1948-49	330·33	4·0268	20·37
1949-50	327·87	4·0018	20·47
1950-51	223·11	3·3191	20·25
1951-52	153·28	2·7465	20·32
1952-53	150·91	2·6920	20·82
1953-54	226·49	3·3448	20·24
1954-55	173·88	2·9089	20·55
1955-56	177·00	2·9238	20·70
1956-57	62·40	1·7341	20·75
1957-58	105·91	2·2485	20·95
1958-59	209·51	3·1670	20·89
1959-60	319·56	3·9368	20·62
1960-61	336·74	4·0516	20·51
1961-62	406·20	4·4617	20·40

Similar results emerge from the calculation of weighted state average yields ($\hat{\bar{Y}}_k$). There is little difference among these average yields with the different weights over the period.

APPENDIX

Shire or Shires	Number	Shire or Shires	Number
Bland	1	Bogan-Marthaguy-Walgett-Coonamble	22
Weddin	2	Peel	23
Narraburra	3	Mandowa-Cockburn	24
Burragong-Boorowa	4	Barraba-Bingara-Macintyre (part)	25
Mitchell	5	Goobang	26
Jindalee-Illabo-Demondrille	6	Jemalong	27
Gundagai-Holbrook-Hume		Gilgandra	28
Kyeamba-Tumbarumba-Tumut	7	Talbragar	29
Coolamon	8	Timbrebongie	30
Lockhart	9	Gulgong (part)	
Coreen (Corowa)	10	Wellington (part)	31
Culcairn	11	Boree-Molong	32
Carrathool-Murrumbidgee	12	Lachlan	33
Berrigan-Jerilderie	13	Lyndhurst-Waugoola	34
Conargo-Murray-Wakool	14	Coolah-Culgong (part)	
Leeton-Wade-Yanko	15	Wellington (part)	35
Liverpool Plains	16	Northern Tablelands	36
Nundle-Tamarang-Warrah	17	Southern Tablelands	37
Ashford-Yallaroi	18	Central Tablelands Residual	38
Coonabarabran	19		
Namoi	20		
Boolooroo-Boomi	21		