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A NOTE ON THE EFFECTS ON YIELDS OF SHIFTS IN THE AUSTRALIAN WHEAT BELT

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There has been a shift in the location of wheat production in Australia since the Second World War. This shift has generally been from higher yielding states such as Victoria to lower yielding states such as Western Australia (see Table 1). The possibility that this shift in location has reduced the rate of increase in average Australian wheat yields has been raised by a number of authors, including Dunsdorfs (1956), Warren (1969), Campbell (1977) and Spriggs (1978).

Vincent, Powell and Dixon (1982) examined the effect on national average wheat yields of the change in the location of production between states in the period 1949–50 to 1976–77. They concluded that the change in the distribution of production between states dampened the rate of increase in national wheat yields from 0.45 per cent to 0.38 per cent per year.

Watson and Duloy (1964) examined the effect of wheat acreage shifts on changes in wheat yields in New South Wales for the period 1930–31 to 1961–62. Despite wide differences in yields and yield variability in the regions, they found little change over that period in mean or variance of New South Wales wheat yields due to shifts in location between regions.

TABLE 1

Wheat Area and Yield by State, 1945–46 to 1980–81

State	Percentage of total wheat area		Mean yield 1945–46 to 1980–81	Yield variance 1945–46 to 1980–81
	1945–46	1980–81		
	%	%	t/ha	t/ha
New South Wales	33.0	29.6	1.23	0.17
Victoria	28.5	12.7	1.41	0.13
South Australia	18.9	12.8	1.12	0.10
Western Australia	16.1	38.4	0.97	0.04
Queensland	3.4	6.4	1.29	0.19
Australia	100.0	100.0	1.17	0.06

Source: Australian Bureau of Statistics.

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The aim is to extend and update the analysis of Vincent et al. (1982) and Watson and Duloy (1964), to measure the effects of shifts in the location of wheat production on the mean and variance of aggregate wheat yields.[1] Analysis of changes over the period 1945-46 to 1980-81 is carried out at two levels: (a) the effect of shifts between states on Australian yields; and (b) the effect of shifts between shires on New South Wales yields.

Methodology

Effects on aggregate yields

The yield of a group of regions in year t is defined as:

$$Y_t = \sum_{i=1}^{n} p_{it})/(\sum_{i=1}^{n} a_{it}) \tag{1}$$

where Y_t is the yield (tonnes per hectare) in year t; a_{it} the area (hectares) and p_{it} the production (tonnes) in region i and year t; and n is the number of regions in the aggregate. Yield per hectare in each region in year t is defined as:

$$y_{it} = p_{it}/a_{it} \tag{2}$$

If total area is defined as $A_t = \sum_{i=1}^{n} a_{it}$, (1) becomes:

$$Y_t = \sum_{i=1}^{n} (y_{it}\, a_{it}) \,/\, A_t \tag{3}$$

The proportion of the total area grown in region i in year t is defined as $r_{it} = a_{it}/A_t$. Then:

$$Y_t = \sum_{i=1}^{n} (y_{it}\, r_{it}) \tag{4}$$

The effect of a shift in location between regions on the aggregate yield is measured by comparing the observed yield each year with the aggregate yield predicted in each year from the distribution of production in some base year. This series of predicted yields can be calculated by weighting the observed yield in each region by the region's share in total wheat area in the base year. Thus:

$$H_t = \sum_{i=1}^{n} (y_{it}\, r_{ib}) \tag{5}$$

where H_t is the predicted aggregate yield in year t and r_{ib} is the proportion of total wheat area sown in region i in base year b. The ratio of the predicted to the observed yield in each year is a measure of the location effect on yields.

[1] The term 'aggregate' wheat yield is used to denote Australian or New South Wales yield rather than the 'average' or 'mean' used by Watson and Duloy (1964), since the national, state or regional yield is an actual yield, based on aggregate production and area.

Effect on yield variance

Because the yields in each region are not independent, covariances are taken into account when the variance $V(Y_t)$ of the aggregate yield in year t is calculated. The variance of aggregate yield is:

$$V(Y_t) = \mathbf{R}_t' \, \mathbf{X}_t \, \mathbf{R}_t \tag{6}$$

where $\mathbf{X}_t$ is the variance–covariance matrix of regional yields, $\mathbf{R}_t$ is a column vector with elements r_{it}, and $\mathbf{R}_t'$ is the transpose of $\mathbf{R}_t$. If $\mathbf{a}_t$ is defined as a column vector of regional areas in year t with elements a_{it}, and if $r_{it} = a_{it}/A_t$ is substituted in (6), then

$$V(Y_t) = (1/A_t^2) \, \mathbf{a}_t' \, \mathbf{X}_t \, \mathbf{a}_t \tag{7}$$

The effect of a shift in location on the variance of the aggregate yield is estimated by measuring the influence of changes in the vector $\mathbf{R}_t$. It is not possible to estimate this directly since data are not available on the variances and covariances for each region in each year. Information on variance and covariance is thus obtained from a time series of regional yields which involves the assumption that the variance is constant over time. Available data preclude any test of this assumption, although Watson and Duloy (1964) considered that because mean yields of shires were not increasing through changing cultural practice, and the variance due to climate was constant, it was likely that variances were not changing over time. This assumption was more difficult to justify for this analysis since there were positive yield trends in all states and in most shires in New South Wales over the period 1945–46 to 1980–81. Nevertheless, the lack of data makes the assumption necessary. Thus for the variance analysis it is assumed that the yield variance of each region is constant over time (that is, $\mathbf{X}_t = \mathbf{X}$), so that estimates based on variance over 36 years are used to approximate the variance in any year of the period.

$\mathbf{X}$ was estimated by $\hat{\mathbf{X}}$ and estimates of the variance of the aggregate yields for each year were calculated as:

$$V(Y_t) = (1/A_t^2) \, \mathbf{a}_t' \, \hat{\mathbf{X}} \, \mathbf{a}_t \tag{8}$$

It is evident that, since A_t is given for each year, $V(Y_t)$ will vary only when the proportion of area in each region changes.

Shifts in Location Between States

The analysis of Vincent et al. (1982) was extended by nine years to the period 1945–46 to 1980–81. Predicted yields were calculated from equation (5), using 1945–46 as the base year. The average aggregate yield of the period was 1.167 ± 0.039 tonnes per hectare and the average predicted yield was 1.211 ± 0.048, that is, a difference of 0.044 ± 0.013 tonnes per hectare. The ratio of predicted and observed aggregate yields for Australia is shown in Figure 1. The fact that the ratio is greater than unity shows that the predicted yield increased faster than the observed yield, indicating that the shift between states has dampened the rate of increase of Australian wheat yields.

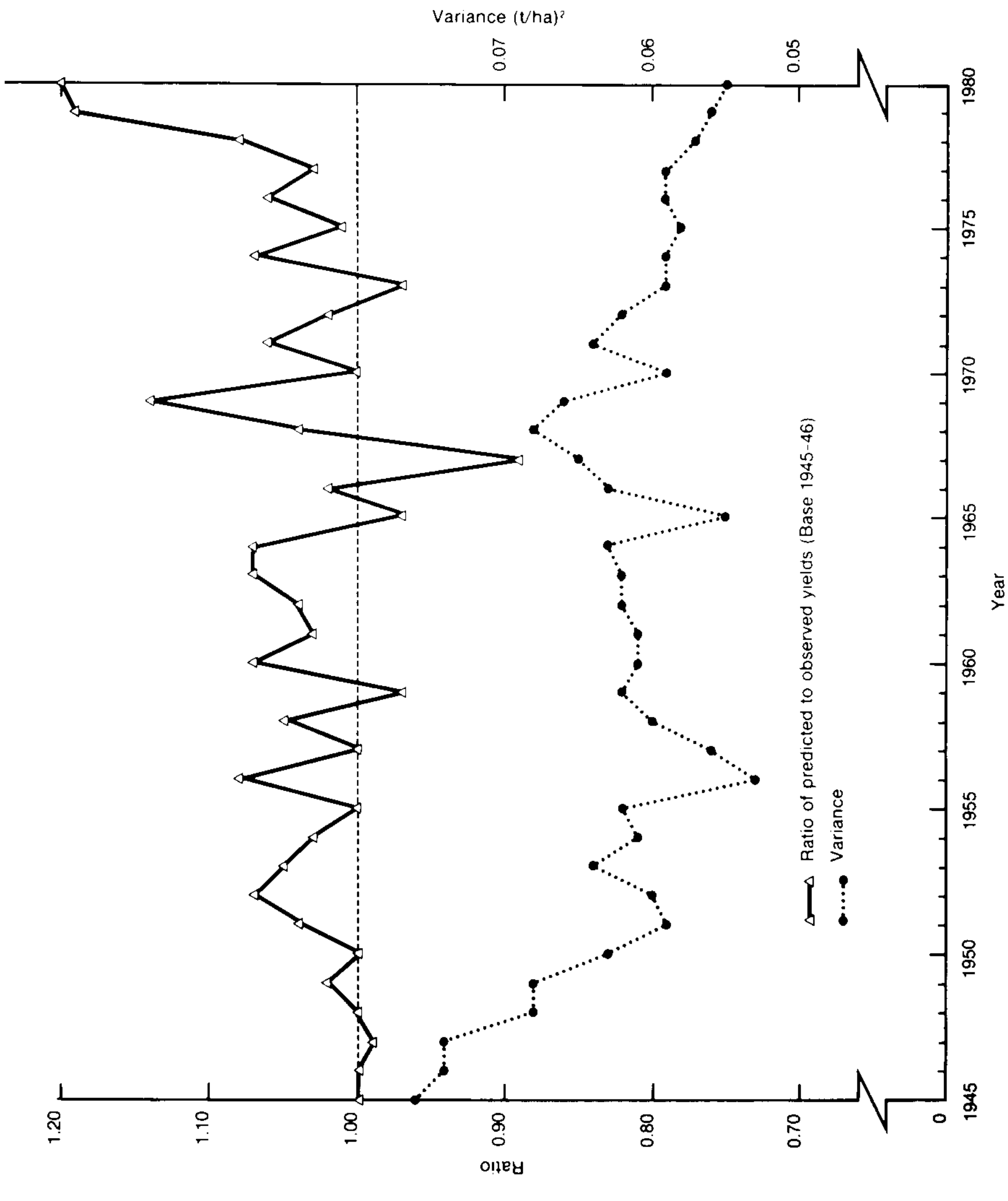

FIGURE 1 — Effect of Shift in Location on Yields and their Variance: Australia

A time trend was fitted to observed and predicted yields. The average rate of increase in observed yields was 9.0 ± 3.5 kilograms per hectare per year between 1945–46 and 1980–81. If the location of production had remained as in 1945–46, the average rate of increase per year would have been 11.9 ± 4.0 kilograms per hectare. The expected yield in 1980–81 was 1.33 ± 0.06 tonnes per hectare but would have been 1.43 ± 0.07 tonnes per hectare if the location had remained as in 1945–46. These results confirm the finding of Vincent et al. (1982) for the shorter period.

The variance–covariance matrix of state yields has been estimated (see Table 2). Western Australia had the lowest variance, followed by South Australia, Victoria, New South Wales and Queensland in that order.

The estimated variance of Australian yields for each year from 1945–46 to 1980–81 was calculated from equation (8) and is also illustrated in Figure 1. There was a reduction in variance over the period as a result of the shift between states, reflecting the increasing importance of Western Australia. The variance fell from 0.076 tonnes per hectare to 0.055 tonnes per hectare, although the movement was not regular. The variance dropped from 1945–46 to the mid-1950s, increased until the early 1970s, and declined after that time.

Shift in Location Between Shires in New South Wales[2]

The effects on New South Wales wheat yields of the change in distribution of wheat area between shires were also investigated. Data on 48 wheat-growing shires for the period 1945–46 to 1980–81 were used, covering over 90 per cent of the area sown to wheat in New South Wales. To make the coverage complete, the 'rest of New South Wales' was treated as shire 49. Between 1945–46 and 1980–81, there has been a shift toward shires with relatively low yields (Table 3).

The analysis of this shift on New South Wales yields was carried out using equation (5), with 1945–46 as the base year. Again, although it varies from year to year, the overall impact of the shifts between shires has been to depress the New South Wales wheat yields (Figure 2). From trend analysis, the average rate of increase of observed yields was 13.7 ± 6.3 kilograms per hectare, compared with the rate of increase of 16.3 ± 6.2 kilograms per hectare in the predicted series using 1945–46 as

TABLE 2

Variance–Covariance Matrix of State Wheat Yields (t/ha), 1945–46 to 1980–81

State	New South Wales	Victoria	South Australia	Western Australia	Queensland
New South Wales	0.17				
Victoria	0.09	0.13			
South Australia	0.07	0.09	0.10		
Western Australia	0.03	0.01	0.01	0.04	
Queensland	0.11	0.04	0.05	0.03	0.19

TABLE 3

Wheat Area and Yield in Selected New South Wales Shires, 1945–46 to 1980–81

Shire	Percentage of total state wheat area 1945–46	Percentage of total state wheat area 1980–81	Mean yield 1945–46 to 1980–81	Yield variance 1945–46 to 1980–81
	%	%	t/ha	t/ha
Boolooroo	0.7	3.4	1.29	0.27
Gunnedah	3.6	2.9	1.32	0.29
Warren	0.1	2.0	1.04	0.31
Parkes	6.6	3.2	1.19	0.22
Carrathool	2.3	3.9	1.07	0.16
Cowra	2.0	0.9	1.51	0.31
Junee	1.3	1.2	1.43	0.31
Urana	1.6	1.4	1.16	0.13
New South Wales			1.23	0.17

Source: Australian Bureau of Statistics.

a base. The expected yield in 1980–81 was 1.47 ± 0.11 tonnes per hectare but would have been 1.53 ± 0.11 tonnes per hectare if there had not been a shift in location from 1945–46. Thus the net effect of regional shifts has been to depress state yields in contrast to the findings of Watson and Duloy (1964) for the earlier period. This depressing effect occurred in the 1960s and late 1970s, after the period analysed by Watson and Duloy.

The variances of 48 shires ranged from 0.13 to 0.48 tonnes per hectare, with over 60 per cent of shires having variances between 0.20 and 0.30 tonnes per hectare. The variance-covariance matrix of shire yields (Table 4) indicates that, in general, covariances are higher between nearby shires than between shires a greater distance apart.

TABLE 4

Variance-Covariance Matrix of Yields (t/ha) of Selected New South Wales Shires, 1945–46 to 1980–81

Shire	Boolooroo	Gunnedah	Warren	Parkes	Carrathool	Cowra	Junee	Urana
Boolooroo	0.27							
Gunnedah	0.25	0.29						
Warren	0.20	0.23	0.31					
Parkes	0.21	0.22	0.20	0.22				
Carrathool	0.14	0.16	0.16	0.14	0.16			
Cowra	0.18	0.20	0.20	0.20	0.14	0.31		
Junee	0.15	0.19	0.20	0.18	0.16	0.27	0.31	
Urana	0.11	0.13	0.13	0.12	0.12	0.14	0.15	0.13

[2] The data used in this analysis were compiled by Els Wijnen of the Bureau of Agricultural Economics.

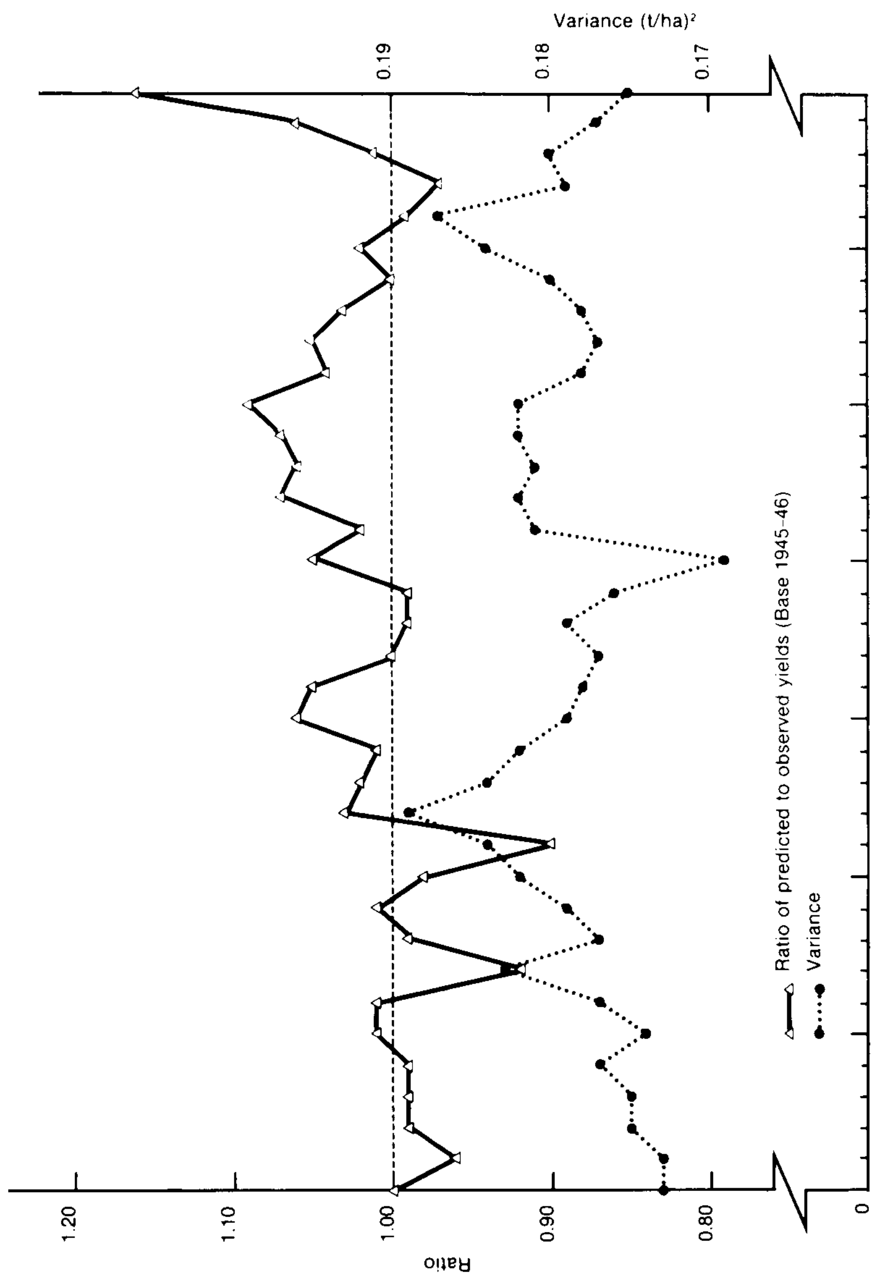

FIGURE 2 — Effect of Shift in Location on Yields and their Variance: New South Wales

The analysis of the effect on the variance of New South Wales yields was also carried out using equation (8), and the results are illustrated in Figure 2. From 1945–46 to 1980–81 the effect on variance of New South Wales yields from the shift in location between shires is minor. Between 1945–46 and the mid-1950s the shift increased yield variance but subsequent shifts eroded this increase by 1980–81. Despite the relatively wide range of variances between shires, the shift between 1945–46 and 1980–81 has generally not taken place from low-variance shires to high-variance shires (or *vice versa*) but has been between shires with similar variance. The shires with the high and low variance have not been among those in which the greatest production shifts have taken place.

Summary and Conclusions

The analysis of shifts between states confirms the dampening effect on Australian wheat yields found by Vincent et al. (1982). The shift in importance from Victoria, South Australia and New South Wales to Western Australia has reduced the rate of increase of Australian wheat yields. In addition, the analysis of shifts between shires within New South Wales shows that the rate of increase in yields in New South Wales has been depressed as a result of a shift from areas with relatively high yields to marginal areas with lower yields. These effects result from the shift from higher yielding to lower yielding areas and do not imply that yields were increasing more slowly in the lower yielding areas.

The analysis of the effects of the shifts on the variance of Australian yields indicated that in general the shift to Western Australia has reduced the variance, as yields in Western Australia have a lower variance than yields in the eastern states. No similar effect was found in the analysis of shires within New South Wales, as the overall shift appears not to have been between high and low variance shires but rather between shires of similar variance.

The observed dampening effect on the rate of increase of Australian wheat yields must be considered when any international comparisons or discussion of the relative performance of wheat (or any other crop) yields in Australia take place, as the national or state yield increases can understate the rate of increase of yields at the farm or regional level. Similarly, any projections of yields at an aggregated level may be misleading if they do not recognise the location effect and the likely effect of future changes in the distribution of wheat plantings among regions.

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