SUPPLY RELATIONSHIPS IN THE AUSTRALIAN WHEAT INDUSTRY: NEW SOUTH WALES*

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I. *Introduction*

In broadest outline, the wheat stabilization scheme in Australia works such that the price per bushel received by farmers can be expressed as below:—[1]

$$P = \frac{P_H (Q_H + Q_G) + P_E (Q_E - Q_G)}{Q} \quad \ldots \ldots \ldots \ldots \quad (1)$$

where P, Q refer to prices and quantities respectively and the subscripts H, G and E refer to the home price and quantity, the volume of "guaranteed" exports, and the average price and quantity of total exports respectively. Q is the sum of the quantities, and P the equalized price per bushel.

For the trivial case where $P_H = P_E$, then $P = P_E$ and the scheme does not exert any effect. Taking P_E as a standard, the following truisms may be written:

$$\text{where } P_H > P_E,\ P > P_E \quad \ldots \ldots \ldots \ldots \quad (2)$$

$$\text{and where } P_H < P_E,\ P < P_E \quad \ldots \ldots \ldots \ldots \quad (3)$$

If the objectives of the scheme are to raise returns to growers and to stabilize aggregate returns, the scheme unequivocally fails during periods when the price relationship described in inequality (3) continues to hold. Not only is the equalized price less than the export price, but it varies directly with the level of output, thus increasing the variance of revenue during such periods. This situation occurred after World War II until about 1952-53.

During periods when $P_H > P_E$, higher returns than in the absence of the scheme may be expected in the short-run.[2] Further, the equalized price varies inversely with the level of output (given that output $> Q_H + Q_G$). However, it is not so easy to draw conclusions concerning the continuation of this price situation as it was above. Copland and Janes have pointed out that "for the satisfactory working of the home price system production should not automatically expand and so in-

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[1] A more detailed description of the form of the successive post-war schemes can be found in Australian Wheat Board, *Annual Report,* 1960-61, pp. 26-27. For an early evaluation of home price schemes see, K. O. Campbell, "Economic Aspects of Agricultural Stabilization Schemes", *Journal of the Australian Institute of Agricultural Science,* Vol. 16, No. 4, (December, 1950), pp. 144-153.

[2] What happens if this situation persists for any length of time depends upon the tolerance of the Treasury (and the taxpayer) and perhaps on the subtlety with which the parameters of the cost of production formula are juggled to produce desired movements in the guaranteed price.

crease the proportion of the product sold at the lower price abroad".[3] Also, if such expansion of production is concentrated at the extensive margin, in less favourable wheat-growing areas, the variance of yield per acre may be increased sufficiently to lead to an overall increase in the variance of aggregate wheat revenues.[4] Further, the scheme will (and has) lead to shifts in the use of resources both within the agricultural sector, and between agriculture and the rest of the economy.[5]

It is intended to study these various aspects of the scheme. However, an important parameter in such an investigation is the elasticity of supply of Australian wheat. It is with the estimation of this elasticity for New South Wales that the present paper is concerned.

II. *Wheat Production in Australia*

Wheat in Australia is produced on farms which also produce a number of other crops—oats, sorghum and other coarse grains, and barley (especially in South Australia). However, the most important alternative to wheat is the production of wool and other sheep products. For instance, in New South Wales, of properties producing 100 acres or more of wheat for grain only 3·2 per cent carried no sheep as at March 31, 1959.[6] The source of income for farms surveyed by the Bureau of Agricultural Economics is shown by states in Table I. It will be noted that the proportions of income derived from different sources varied considerably among the states.

A number of implications for supply analysis can be drawn from the facts noted above. The first is that, with a number of production alternatives, supply may be expected to be considerably more elastic than for products produced with few or no alternatives. Secondly, it is necessary to take explicitly into account the production possibilities open to wheat producers in constructing models to estimate supply elasticities. Thirdly, because the set of competing products varies among states it is apparent that gains in efficiency of estimation are obtainable by disaggregating, rather than by attempting to estimate an aggregate function. The problem associated with this approach has been noted by Cowling and Gardner: "Thus time series studies at the regional level although initially attractive as representing a more homogeneous production area have the drawback that regions are interdependent in production so that aggregate response cannot be obtained by simple additive procedures".[7] Wheat production in Australia takes place over so great a geographical spread and with such diverse alternative products

[3] D. B. Copland and C. V. Janes, *Australian Marketing Problems,* Angus & Robertson, Sydney, 1938, p. xvii.

[4] This hypothesis is currently being tested. Preliminary results suggest that it does not hold.

[5] These effects have been discussed by, amongst others, K. O. Campbell, *op. cit.* J. N. Lewis, *op. cit.* A. J. Little, "Some Aspects of Government Policy Affecting the Rural Sector of the Australian Economy, 1939/45-1953", *The Economic Record,* Vol. 38, No. 83, (September, 1962), pp. 318-340; and F. H. Gruen, "Australian Agriculture and the Cost-Price Squeeze", in *The Australian Economy,* (Melbourne, F. W. Cheshire, 1963), pp. 320-349, especially p. 340.

[6] Derived from data in *Classification of Rural Holdings by Size and Type of Activity,* Bulletin No. 1—New South Wales, Commonwealth Bureau of Census and Statistics, Canberra.

[7] Keith Cowling and T. W. Gardner, "Analytical Models for Estimating Supply Relations in the Agricultural Sector: A Survey and Critique", *Journal of Agricultural Economics,* Vol. 15, No. 3, (June, 1963), p. 444.

TABLE 1

Proportions of Gross Farm Income derived from various enterprises
Average per farm over period 1954-55 to 1956-57

Enterprise	Queensland	New South Wales	Victoria	South Australia	Western Australia	TOTAL SAMPLE
Wheat	0.4486	0.2966	0.5370	0.3827	0.4373	0.4046
Oats	0.0029	0.0119	0.0458	0.0123	0.0194	0.0199
Barley	0.0350	0.0030	0.0410	0.1433	0.0215	0.0439
Sorghum & Maize	0.0550	0.0026	0.0006	0.0001	0.0010	0.0051
Hay & Chaff	0.0009	0.0068	0.0042	0.0053	0.0012	0.0043
Other Crops	0.1823	0.0093	0.0008	0.0096	0.0015	0.0183
Wool	0.0796	0.4469	0.2111	0.2773	0.3892	0.3271
Other Livestock Income	0.1837	0.2156	0.1485	0.1617	0.1219	0.1685
Miscellaneous	0.0117	0.0074	0.0105	0.0077	0.0070	0.0083
Total Income	£7,848	£6,646	£6,391	£6,852	£6,750	£6,725

Source: Derived from Table No. 27, *The Australian Wheatgrowing Industry,* Bureau of Agricultural Economics, Canberra, 1960.

that it was thought that the gains from disaggregating into more homogeneous areas were likely to outweigh the difficulties associated with aggregation.[8] This approach required criteria for selecting homogeneous regions. It is to this problem that we now turn.

The basic unit from which regions were defined was the shires (including municipalities within shires). Because of limitations in the computing facilities available, it was found necessary to restrict the number of basic units to 38. This was done by aggregating a number of adjoining shires before the definition of regions was determined. Details of the shires so treated are presented in Appendix I. Given the remaining 38 units, hereinafter referred to as "shires", it was required to specify a number of criteria for aggregating into homogeneous regions. Three criteria were successively applied.

The first criterion involved that the regions should be uniform in their response to economic stimuli. Because the response variable in the supply analysis was, for the usual reasons, to be a measure of acreage rather than output, this resolved itself into a requirement that acreages over time should be highly correlated within regions.[9] A 38×38 matrix of zero-order correlation coefficients was computed for New South Wales using observations on acreages from 1930-31 to 1961-62.[10] Region VII of Appendix I consisting of a number of tablelands shires, was not included in the final analysis, partly because of a lack of internal homogeneity of the region and partly because of its small contribution to the total production of the state. Intra-regional correlations were high (usually $+0{\cdot}7$ to $+0{\cdot}9$) in the six regions. The inter-regional correlations were also high (usually $+0{\cdot}7$ to $+0{\cdot}9$) for the group of regions I, II, V and VI and for the two regions III and IV, and very low (usually $-0{\cdot}3$ to $+0{\cdot}2$) between these two groups. At this stage we distinguished between two broad classifications of wheat-growing areas. The first consisted of long-established wheat areas of the traditional wheat-sheep belt (I, II, V and VI), the "old areas", and the second consisted of the "new areas", in the north of the state (III and IV).

The second criterion required that the regions be homogeneous with respect to climatic variability. It was assumed that deviations from regressions of yield per acre on time for each shire were mainly due to weather conditions. Such regressions were computed for the 38 shires. However, with 32 observations, only 4 of the 38 shires showed significant trends over time. For this reason, the correlation matrix of the 38 areas was computed using the raw data on yields per acre over the 32 year period.

The information in this matrix alone did not provide a basis for aggregation into regions. This is so because the correlation of yields per acre among areas, reflecting climatic variability, can be expected to be largely

[8] It is not intended to discuss the aggregation problem in this paper. However, an extensive literature exists. For example, see H. Theil, *Linear Aggregation of Economic Relationships,* (Amsterdam: North Holland Publishing Co., 1954).

[9] To validate the use of acreage rather than production data as the response variable in supply analysis, the relationship between yields and price data was investigated. It turned out that no discernible relationship existed.

[10] The supply function results reported here apply only to post-war data. The longer period has been used in the delineation of areas because it is intended to apply the analysis also to pre-war years.

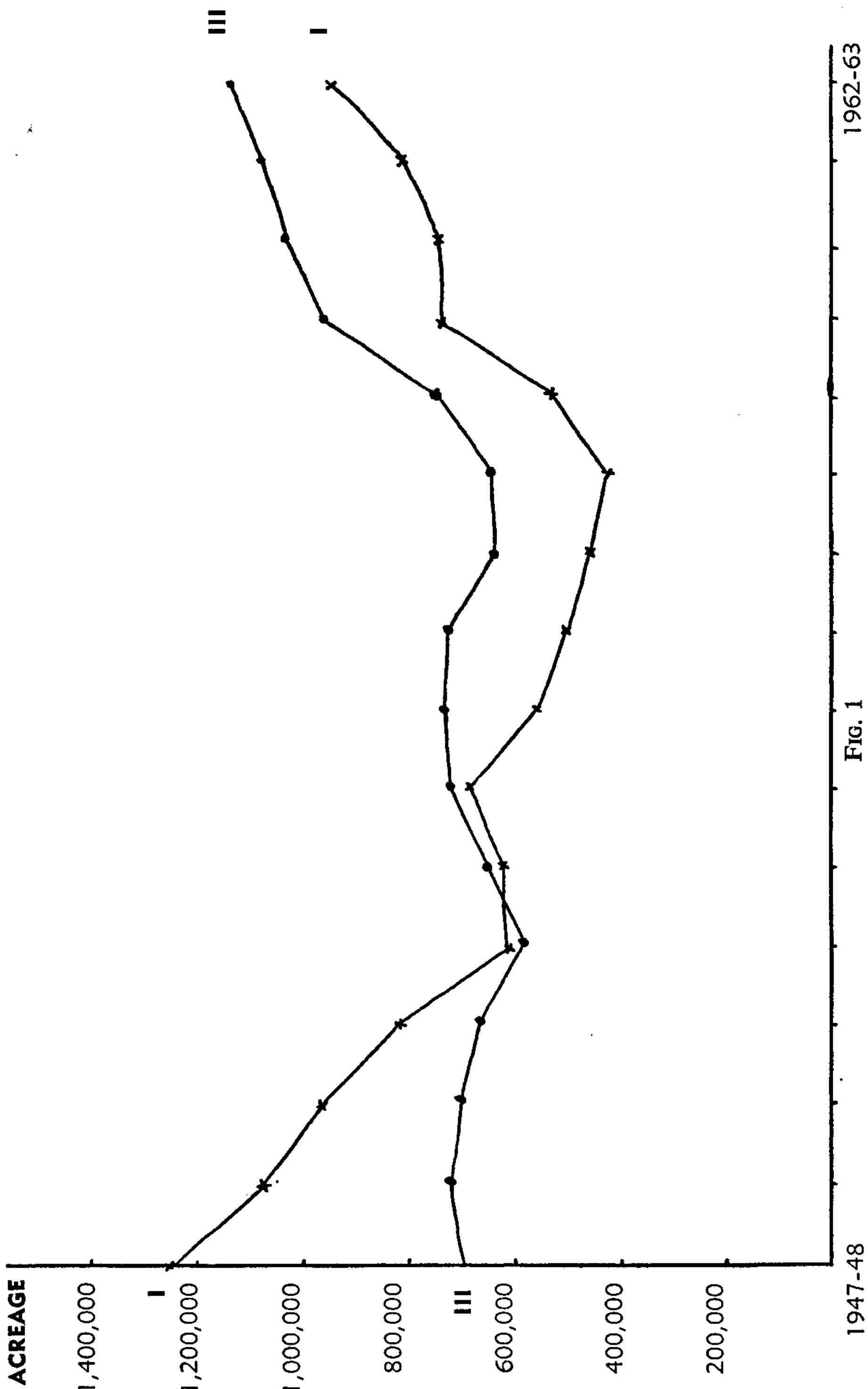
ACREAGE
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
I
III
1947-48
1962-63

FIG. 1

a function of the distance between areas. This in fact was found to be the case. Thus, using different sets of areas as starting points for aggregation, and a given criterion for inclusion into the aggregate, it is possible to construct quite different sets of regions. For this reason, it was decided to impose the further requirement that the regions should coincide with statistical divisions of the state, where consistent with other criteria. In the final outcome, two regions only, I and II, coincided with statistical divisions. Yields generally were more highly correlated within regions than between them, although not so markedly as were correlations of acreages, and intra-regional yield correlations were generally lower than the acreage series, probably due to the relatively high variances of yields.

The basis for the low values of correlation coefficients between old and new areas can be seen by examining Figure I, where "intended" acreages[11] are graphed against time for region I, a typical old area and region III, a new area.

Region I shows the old area pattern of declining then increasing acreages over the time period studied with a net decline. However, Region III shows an overall upward trend. Reasons suggested for this trend are that new wheat varieties for the northern areas became available at about this time; more powerful machinery was becoming available to handle the heavy soils in the area; and there was a growing recognition of the possibilities of premium wheat production. A study by Waring suggests that wheat production was the most profitable activity on a farm in that area over a wide range of prices of wheat and competing products.[12] It seems reasonable to postulate that the observed growth in wheat sowings since about 1956-57 in the new areas was due to the adoption of new technology.

III. *Some Methodological Issues*

It is not proposed to review here the extensive literature on supply analysis. This literature has been reviewed recently by Cowling and Gardner.[13] However, there are some issues which need to be commented upon.

It appears to us that the problems encountered in estimating demand and supply functions are essentially similar.[14] This is so not only in the simultaneity of economic relationships, but mainly in the problems involved in defining the appropriate response variables and the objectives of producers and consumers. Both groups presumably maximize a utility function; both respond to some economic variables with different levels of consumption or output. In both cases it is not easy to define the expectational model for prices, especially important where these are very variable; nor is it a simple matter to specify the lags involved in adjusting consumption or production to the price variable. However, in the

[11] Intentions to sow wheat or "intended" acreages rather than sown acres were used as the response variable in the supply analysis, for reasons discussed below.

[12] E. J. Waring, *Linear Programming Using Farmer Estimated Input-Output Coefficients,* unpublished M.Ag. Ec. Thesis, University of New England, 1962, p. 17 and pp. 185-189.

[13] Keith Cowling and T. W. Gardner, *op. cit.,* pp. 439-450.

[14] See, e.g. the parallel approach in Nerlove's two books, *The Dynamics of Supply,* (Baltimore; the John Hopkins Press, 1958), and *Distributed Lags and Demand Analysis for Agricultural and Other Commodities,* (Washington: U.S. Government Printing Office), 1958.

case of demand analysis, "satisfactory" results are generally obtained even by conventional statistical techniques and models. The same cannot be said of supply analysis.[15] For instance, in a recent study, Gardner obtained negative and erratic supply elasticities, although he was using the latest gadgets from the toolkit,[16] including the Klein method of estimating distributed lag models.[17] On the other hand, using simple least-squares procedures, useful results are often obtained in estimating the parameters of far more complex economic relationships than the supply function for a rural industry.[18] It is tempting to draw the conclusion that, where farmers in fact respond to a price variable, this response will be detected in empirical studies using the simplest techniques, so long as variables are correctly specified.[19] It may be that a more useful line of research could lie in determining the reasons for the lack of supply response of farmers in situations where this is observed[20] than in seeking refinements in estimating techniques.

In the case of the present study, indications of a strong supply response were noticed by simply graphing acreage and relevant price variables.

The first step in formulating a model involves the definition of appropriate variables; then relationships between these can be specified. The response variable we used was the acreage of wheat intended to be sown in the following season for all purposes. The use of this variable involves two main assumptions. It was assumed that farmers' *statements* of their intentions bear some constant relationship to what they actually plan to do. It turns out that intentions data are collected in March from one to three months before wheat sowings commence; and that intended acreage and actual acreage were highly correlated over the period studied. The differences between them, in 1956-57 for example, could generally be accounted for by weather conditions. It is because intentions data are less subject to short-run climatic influence than actual sowings that we

[15] An explanation for the difference in the success achieved in estimating the two functions has been suggested as follows:— "The striking difference in what we know about supply has not come about because one has received our attention while the other has been neglected. The difficulty runs much deeper than this. For a function to be useful it must either be stable over time, or we must be able to predict how it will change. The stability of the function underlying the demand is dependent upon what happens to 'tastes' and in the case of supply upon 'technology'. We observe, however, whereas tastes remain fairly constant, technology does not." T. W. Schultz, "Reflections upon Agricultural Production, Output and Supply", *Journal of Farm Economics,* Vol. 38, No. 3, (August, 1956), p. 750. This explanation takes no account of the impact of technology upon the consumer in new products, new methods of packaging, new advertising techniques influencing tastes, and so forth.

[16] T. W. Gardner, "The Farm Price and the Supply of Milk", *Journal of Agricultural Economics,* Vol. 15, No. 1, (May, 1962), pp. 58-73.

[17] L. R. Klein, "The Estimation of Distributed Lags", *Econometrica,* Vol. 26, No. 4, (October, 1958), pp. 553-565.

[18] For example see, J. W. Neville, "A Simple Econometric Model of the Australian Economy", *Australian Economic Papers,* Vol. 1, No. 1, (September 1962), pp. 79-94. See, also, however, J. H. Duloy, "A Simple Econometric Model of the Australian Economy—A Methodological Comment", *Australian Economic Papers,* Vol. 2, No. 1, (June, 1963), pp. 121-123.

[19] For example, Helen C. Farnsworth and William O. Jones, "Response of Wheat Growers to Price Changes: Appropriate or Perverse?", *The Economic Journal,* Vol. LXVI, No. 262, (June, 1956), pp. 271-287.

[20] An example of such a study is that of Campbell. See K. O. Campbell, "The Inelasticity of Supply of Wool", *The Economic Record,* Vol. 31, No. 2, (November, 1955), pp. 311-318.

used them as the response variable. It was further assumed that intended sowings of wheat *for all purposes* is appropriate in a "wheat for grain" supply function, although on occasions some of the crop is not in fact harvested for grain, but is abandoned, grazed, or harvested for hay. The justification here is that, in the wheat areas, any sowings of wheat which in fact yield a crop are almost certain to be harvested; so that the price paid for grain influences decisions to sow even those crops ultimately converted to hay.

We further assumed, in respect of the old-established wheat areas, that intended acreages approximate "long-run equilibrium acreages", as defined by Nerlove.[21] This was a rather stronger assumption. If it can be maintained, it avoids the ambiguity of interpretation of distributed lag models referred to by Nerlove and others.[22] This ambiguity arises since lags in adjustment of acreage can arise both from lags in the formation of price expectations and from lags in adjustment of resources. The separation of these influences requires some assumption concerning one of the two causes of lag.

The assumption that lags in resource adjustment can be ignored may be justified by the fact that for the old areas over the period studied, the acreage of wheat at no time exceeded the acreage attained during the first season of the period, and wheat-producing machinery was at least maintained during subsequent seasons at the level of that year, in spite of a decline in acreages. The appropriate data are presented in Appendix II. It is thus contended that the usual barriers to rapid supply adjustment, the availability of suitable land and machinery, did not exist over the period of the study. It should be noted that this assumption is required only to allow estimates of parameters of the price expectation model. Elasticity estimates do not depend on it.

For New South Wales wheat areas the appropriate price variables are those for wheat and wool.[23] The wool price used was the Australian average price per pound greasy obtained during the year ending June 30 during which the wheat crop was sown. Some refinements of this price variable are immediately apparent. These involve using an index of prices of different types of wool weighted in the proportions produced in the wheat areas, and using an average for the period up to the time when the intentions data are collected. It is thought that these improvements will involve little change in the results, but they are being checked in respect of a number of areas. The wheat price involves more difficulties. This is so because, when intentions for the season in year t are formulated, farmers are not aware even of the wheat price obtained for year $t-1$. The first advance for year $t-1$ is not a good guide even to that year's price—the correlation coefficient between (deflated) first advances and (deflated) final realizations was $-0\cdot09$ over the period. No satisfactory solution was obtained. It was decided to use the equalized price for the crop last harvested as the price appropriate to the current crop. Some information, at least, is available to farmers in respect of this price. They are aware of the home consumption price to be paid on a large proportion of the crop and statements concerning the sale abroad of the crop

21 See Nerlove, *The Dynamics of Supply, op. cit.*, pp. 61-62.

22 *Ibid*, p. 186 *et. seq.* and pp. 236-254 and Gardner and Cowling, *op. cit* p. 446.

23 The computational model used later has been anticipated in defining the price variables with a lag.

are published in the press. Because of the stabilization scheme, wheat prices do not vary greatly from year to year, so that this definition is not so bad as it would be if prices were extremely variable from year to year.

The models of supply used were two: Nerlove's model of adaptive expectations and a "traditional" model of extrapolative expectations. The justification for the use of the Nerlove model, in spite of its limitations, lies in the variability of wool prices. The model specifies that farmers adjust supply to expected "normal" price rather than to current price. The "traditional" model was estimated partly for comparative purposes and partly to indicate how much of the variability of the acreage series was accounted for by the price variables above, the Nerlove model generally producing high values of R^2 due to the inclusion into the model of a lagged value of the endogenous variable.

The prices which actually entered the model were the ratios of wheat to wool prices, rather than absolute values of the prices deflated by some index.[24] No firm *a priori* reason existed for the preference for the ratio. The usual trick of examining the data beforehand by graphical methods was indulged in.[25] Some initial preference was maintained for the price ratio because it is more closely identified with the analysis of shifts in output in a two-product situation using the concept of an iso-resource function.

The use of a ratio in a supply function has a number of implications. Firstly, it involves an assumption that the elasticity of supply with respect to equi-proportional changes in the prices of both products is zero. This may be approximately true for the total supply function of an agricultural region for much the same reasons as the low total supply elasticity of agriculture as a whole.[26] Secondly, the elasticity valued at given values of the variables is the same with respect to the ratio as with respect to the numerator, and is the same in absolute value but of opposite sign as with respect to the denominator. Also, given that the elasticity with respect to the numerator is positive, the elasticity with respect to the numerator is a decreasing function of the denominator. This states, for our model, that the elasticity of supply of wheat, for a given wheat price is higher for low wool prices than for high.[27]

The models may now be written as below:

$$x_t = a_o + a_1 P_t^* + u_t \quad \ldots\ldots\ldots\ldots \quad (4)$$

where x_t is the acreage in question and P_t^* is the expected normal price ratio. In the traditional model of extrapolative expectations,

$$P^*_t = P_{t-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

where $P_t - {}_1$ is the observed price ratio in the previous period. This model may now be written:

$$x_t = a_0 + a_1 P_{t-1} + u_t \quad \ldots\ldots\ldots\ldots \quad (6)$$

24 For comparison, results obtained using the latter model are included in Appendix III.

25 This implies, of course, that the usual statistical tests are not strictly applicable.

26 See D. Gale Johnson, "The Nature of the Supply Function for Agricultural Products", *American Economic Review,* Vol. XL, No. 4, (September, 1950), pp. 539-564.

27 In the case of these two products, it is not clear which way we would expect this relationship to go.

For the model of adaptive expectations,

$$P_t^* - P_{t-1}^* = \beta[P_{t-1} - P_{t-1}^*] \quad \ldots\ldots\ldots\ldots (7)$$

where β is the "coefficient of expectation".

By simple manipulations we can transform equations (4) and (7) into a relationship between observable variables.

$$x_t = a_0\beta + a_1\beta P_{t-1} + (1 - \beta)x_{t-1} + v_t \quad \ldots\ldots (8)$$

$$\text{where } v_t = u_t - (1 - \beta)\, u_{t-1} \quad \ldots\ldots\ldots\ldots\ldots (9)$$

Following Nerlove, we shall call the model of extrapolative expectations (leading to equation (6)) the "static model", and the model of adaptive expectations, (leading to equation (8)) the "dynamic model".

Some problems of estimation arise with respect to the dynamic model, which includes a lagged value of the endogenous variable. These have been discussed, and consistent estimators developed by Hannan.[28] Least-squares estimates of the parameters of (8), the estimating equation for the dynamic model, are biased. This is so because x_{t-1} is generally correlated with the disturbance, v_t, by (9).[29] The bias is thus similar in origin to that which exists in least-squares estimates of equations including current endogenous variables amongst the explanatory variables. It is not unexpected then, that asymptotically unbiased and consistent estimators can be derived along the lines of Theil's two-stage least squares.[30] Such an estimator has been derived by Liviatan.[31]

The bias of classical least-squares estimates of distributed lag models compared with asymptotically unbiased estimators can thus be considered in the same way as have similar problems arising with small-sample estimates of "simultaneous" equations. There exists a tendency amongst empirical workers in econometrics to put forward the claim that the asymptotic properties of the "simultaneous" estimators are not sufficient grounds for their use where small samples are involved.[32] Further, least-squares estimates have generally smaller variances,. and are, moreover, frequently very close to estimates obtained by the other methods.

In the case at hand, there are 16 observations only available. As wheat production is an annual phenomenon, we cannot have recourse to monthly data to increase the number of observations. We have adhered to classical least-squares estimates; but, for comparison, have included estimates in Appendix III using Liviatan's consistent estimator.

If the suggestion that an innovation process has occurred in the new areas is accepted, then a different approach is required for these areas.

[28] E. J. Hannan, "The Estimation of Relationships Involving Distributed Lags", paper read at the Econometrics Seminar, Adelaide, August, 1963.

[29] Least-squares estimates of the parameters have the usual desirable properties when u_t follows the simple autoregressive scheme:
$u_t = \alpha u_{t-1} + w_t$; $\alpha = (1-\beta)$, and w_t has the usual properties of the disturbances in the least-squares assumptions. In this case $v_t = w_t$. See Nissan Liviatan "Consistent Estimation of Distributed Lags", *International Economic Review,* Vol. 4, No. 1, (January, 1963), pp. 44-52.

[30] H. Theil, *Economic Forecasts and Policy,* (Amsterdam: North Holland Publishing Co., 1958). pp. 223-229.

[31] Nissan Liviatan, *op. cit.*

[32] For example, see Carl F. Christ, "Aggregate Econometric Models", *The American Economic Review,* Vol. XLVI, No. 3, (June, 1956), pp. 385-408 and especially 397-401.

An appropriate model may be one similar to that developed by Powell, Polasek and Burley for the situation where a new product is introduced into a market where there exist close substitutes.[33] The model allows the rate of increase of the share of the market of the new product, and the equilibrium share of the market after the adoption process has worked itself through, to be a function of relative prices of the products. We have not yet defined in precise terms such a model appropriate to the new areas. However, the applicability of such a model has been crudely tested by first fitting an exponential trend of acreages against time and then computing the correlation between deviations from the trend and the ratio of prices of the products.

IV. *Results*

All results apply to the period 1947-48 to 1962-63. The results estimated by least-squares for the four old areas are presented in Table 2, with intended acres as the response variable. Similar results with actual acres as the response variable appear in Appendix III. A comparison of these results suggested that the main effect of using intentions data was to reduce the variance of estimates, the coefficients being very similar in all cases. That is, the use of intentions data reduced the effect of climatic influences upon wheat sowings.

It will be recalled that least-squares estimates of these parameters are (generally) not consistent. Results were obtained using Liviatan's consistent estimator for the dynamic model for intentions data. These appear in Appendix III. It turned out that these results were very similar to the results obtained using least-squares.

The estimates for the old areas in Table 2 exhibited a reassuring degree of consistency among the regions, and even between the dynamic and static models. The ratios between the regression coefficients of the price ratio and their standard deviations were gratifyingly large in all cases. The signs of all the estimated coefficients were as expected. Such consistency is rare in supply analysis,[34] and leads us to place more reliance on the estimates than we would otherwise do.

The coefficient of expectation, β, for the four areas, I, II, V and VI was 0·44, 0·63, 0·47 and 0·63 respectively. It can be shown for the model of adaptive expectations used here that the expected normal price is a weighted average of past prices, with the weights declining from recent to less recent periods:[35]

$$P_t^* = \sum_{\lambda=0}^{t} \beta(1-\beta)^{t-\lambda} P_{\lambda-1} \qquad \ldots\ldots\ldots\ldots \quad (10)$$

The sum of the weights over the first N past observed prices is[36]

$$S_N = 1 - (1-\beta)^N \qquad \ldots\ldots\ldots\ldots \quad (11)$$

[33] Alan Powell, Metody Polasek and Harry T. Burley, "Synthetic Fibres in the Wool Textile Industry: A Study of the Role of Price in Technological Adjustment", *Australian Journal of Agricultural Economics,* Vol. 7, No. 2, (December, 1963), pp. 107-120.

[34] See e.g. Gardner, *op. cit.,* and Marc Nerlove and William Addison, "Statistical Estimates of Long-Run Elasticities of Supply and Demand", *Journal of Farm Economics,* Vol. 50, No. 4, (November, 1958), pp. 561-579.

[35] Marc Nerlove, *The Dynamics of Supply, op. cit.* p. 54.

[36] *Ibid,* p. 187.

TABLE 2

Regression Estimates for Old Wheat Regions Calculated Using Intentions to Sow as Response Variable. (a)

A. *DYNAMIC MODEL*

Region	Regression Coefficients		Elasticity at the Mean		R^2
	$a_1\beta$	$(1-\beta)$	Short-run	Long-run	
I	+0.129 (0.028)	+0.557 (0.099)	+0.473	+1.067	0.91
II	+0.107 (0.032)	+0.577 (0.133)	+0.373	+0.881	0.84
V	+0.026 (0.005)	+0.534 (0.107)	+0.325	+0.698	0.89
VI	+0.179 (0.047)	+0.372 (0.165)	+0.416	+0.662	0.82

B. *STATIC MODEL*

Region	Regression Coefficient a_1	Elasticity at the Mean	R^2
I	+0.219 (0.048)	+0.678	0.68
II	+0.181 (0.041)	+0.629	0.59
V	+0.038 (0.007)	+0.480	0.66
VI	+0.249 (0.039)	+0.580	0.75

(a) The figures in brackets under regression coefficients are standard deviations.

which can be made as close to one as we may please by taking N large enough. S_N depends on the size of β; for a value of β close to one, only relatively few past prices need to be included in order that S_N differ from one by an arbitrarily small amount. The number of years which need to be taken into account so that the sum of the weights differed from one by 0·05 is 4 to 5 years for all regions. Thus, the effects of a particular price ratio in any one year can be expected to last for a period of 4 to 5 years, due to its (declining) influence on the expected normal price.

Poor results were obtained when subjecting the data for the new areas to the ratio models. These results also appear in Appendix III. Of interest is the "improvement" in the values of R^2 obtained for the dynamic model (0·86 and 0·92 for Regions III and IV respectively) over those obtained for the static model (0·15 and 0·09). This reflects only the upward trends in acreage in the two regions during the period of the study.

No reliance can be placed on the results using the above models for the new areas. For these areas an exponential time trend was fitted to acreage intentions, and the disturbances correlated with the price ratios, as a crude test of the applicability of a price-accelerated-trend model. These regressions for areas III and IV were both significant at the one per cent level. The correlation coefficients of the disturbances from trend against the price ratio were 0·79 and 0·72 respectively. These results indicate that it is worth proceeding with a more complex model for the new areas.

Also presented, in Appendix III, are results computed for a model where both prices are included separately, instead of as a ratio. This model has the general form:

$$x_t = a_o + a_1 P_{1t}^* + a_2 P_{2t}^* + u_t \quad \ldots \ldots \quad (13)$$

where x_t is defined as previously, P_{1t}^* is the expected normal (deflated) price of wheat, and P_{2t}^* is the expected normal (deflated) price of wool. For both static and dynamic models, it was assumed that $P^*_{1t} = P_{1t-1}$, because of the relative constancy and certainty of wheat prices. For the two expectational models, similar functions for P_{2t}^* are assumed as for the price ratio models. (Equations (5) and (7)). The results obtained for models of the type of equation (13) are very poor.

V. *Conclusions*

(i) *Methodology*

Where some uncertainty exists concerning the small sample properties of alternative estimators, empirical studies can yield some insights. In the present study, there were only small differences (although uniform among the regions) between estimates obtained by least-squares and by a consistent estimator. We have accepted the least-squares estimates. For the new areas, high values of R^2 and high values of the "long-run elasticity", were obtained for the dynamic model because of the strong serial dependence on the acreage series. These results illustrate some of the pitfalls existing in an uncritical use of distributed lag models for supply analysis where trends occur in the response variable. It is not acceptable merely to include a trend term in the model of the supply function, because the trend itself may well be a function of prices.

(ii) *Implication of Estimates*

The long-run elasticity estimates for the old areas of New South Wales ranged from +0·662 to +1·067. The correlations obtained for the new areas, between the disturbances from trend and the price ratio, suggested that these areas, also, were responsive to the relative prices of wheat and wool. It is not possible at this early stage of the study to draw firm conclusions for policy purposes: we must wait until results are available for the other states. However, if we are prepared to assume that New South Wales results are representative of Australia as a whole, then some conclusions may be drawn.[37] In fact, New South Wales is the largest wheat producing state in Australia.

[37] It is probable that the supply elasticity is less in the other states, as farms in these states derive a greater proportion of their income from wheat than farms in New South Wales.

Because of the responsiveness of wheat acreage (and hence production) to the relative prices of wheat and wool, it seems likely that very considerable revenue losses were sustained during the operation of the stabilization scheme when $P_E > P$. The Australian Wheat Board has estimated that sales of wheat during this period would have realized some £198 millions more had wheat been sold at export prices.[38] This calculation is based on the actual production of wheat during the period. It does not take account of the losses of production incurred by paying farmers the lower, equalized price of wheat.[39] Just how great the actual losses were depends, amongst other things, upon the elasticity of demand for Australian wheat. We guess that demand was not inelastic over the early post-war years, so that the Wheat Board's calculations represent a considerable understatement of actual revenue losses.

Whatever the success of the stabilization scheme may have been in reducing the variability of the *price* of wheat it has not had similar success in stabilizing the acreage. It does not take account of a major determinant of wheat acreage, the price of wool.

This is the greatest single weakness of the scheme, which is based on the fiction that the Australian Wheat Industry is a separate entity. Whilst stabilizing the price of wheat, the scheme allows wheat production to fluctuate inversely with the price of wool. It would be purely fortuitous if a price ratio were realized such as to produce an output of wheat appropriate to the state of demand for the two commodities.

Any forecasts of the future course of the scheme must involve some consideration of trends in wool prices. In this regard, the authors tend to be pessimistic—we suspect that the success of *currently available* synthetics is cause enough to be anxious about the impact of future synthetics. If wool prices do trend downwards, then the comments of Copland and Janes in the thirties, cited at the beginning of this paper, may have a modern relevance. At all events, we believe that the recent decision of the Commonwealth Government to subsidize the promotion of wool will be, if wool promotion is successful, a step towards stabilizing the wheat industry.

APPENDIX I

Formation of Regions from Shires and Shire Aggregates

The criteria for the selection of homogeneous regions have been described in the text. The 38 shires to which these criteria were applied were either individual shires or aggregates of adjoining shires within the same statistical division. Shires, obviously, vary in area of wheat grown as well as in geographical area. The aim was to have shires or shire-aggregates of at least about 100,000 acres of wheat for grain at some stage in the 32 year period for which data were collected. Some shires, of course, grow far more.

Some shire boundaries have changed over this period. Fortunately, the Bureau of Census and Statistics maintains the convention of continuing separate publication of statistics where shire boundaries change

[38] Australian Wheat Board, *Annual Report*, season 1955-56, p. 30.

[39] The calculation of revenue losses from wheat sales does not of itself have much significance. It is necessary to take account also of effects on wool output, on the feed grain industries, on home consumption and so forth.

so that the one shire is in 2 statistical divisions, (note numbers 25, 31, 35).

In the following key the same names for shires have been used as in the B.A.E. publication "The Variability of Wheat Yield per Acre from 1949-50 to 1958-59—New South Wales".

REGION I—South Western Slope Statistical Division

Shire or Shires	*Number*
Bland	1
Weddin	2
Narraburra	3
Burrangong-Boorowa	4
Mitchell	5
Jindalee-Illabo-Demondrille	6
Gundagai-Holbrook-Hume-Kyeamba-Tumbarumba-Tumut	7

REGION II—Riverina Statistical Division

Shire or Shires	*Number*
Coolamon	8
Lockhart	9
Coreen (Corowa)	10
Culcairn	11
Carrathool-Murrumbidgee	12
Berrigan-Jerilderie	13
Conargo-Murray-Wakool	14
Leeton-Wade-Yanko	15

REGION III—Shires in Northern New South Wales with large acreage increases in recent years.

Liverpool Plains	16
Nundle-Tamarang-Warrah	17
Ashford-Yallaroi	18
Coonabarabran	19
Namoi	20
Boolooroo-Boomi	21

REGION IV—A "new" area separated from III because of greater climatic variability.

Bogan-Marthaguy-Walgett-Coonamble	22

REGION V—Old established wheat growing areas in Northern New South Wales.

Peel	23
Mandowa-Cockburn	24
Barraba-Bingara-Macintyre (part)	25

REGION VI—"Central" New South Wales.

Goobang	26
Jemalong	27
Gilgandra	28
Talbragar	29
Timbrebongie	30
Gulgong (part)—Wellington (part)	31
Boree-Molong	32
Lachlan	33
Lyndhurst-Waugoola	34
Coolah-Gulgong (part) Wellington (part)	35

REGION VII

Northern Tablelands	36
Southern Tablelands	37
Central Tablelands Residual	38

APPENDIX II

Numbers of Various Types of Machinery on Rural Holdings at 31st March
New South Wales

Number of Machines[a]

Year	Grain Drills	Header, Strippers, and Harvesters	Tractors on the Slopes	Tractors on Plains and Riverina
1947	25,266	17,560	7,792	5,035
1948	25,427	16,984	8,127	5,225
1949	25,465	16,881	8,835	5,900
1950	25,789	16,886	10,377	6,939
1951	26,132	17,095	11,861	8,064
1952	25,899	17,481	13,415	9,224
1953	27,047	17,845	14,535	10,067
1954	27,395	17,846	14,995	10,527
1955	28,142	18,030	15,912	11,248
1956	30,756	19,224	17,251	12,363
1957	30,462	19,118	17,794	12,612
1958	31,033	17,564	18,528	13,426
1959	30,131	16,711	18,711	13,509
1960	30,956	18,206	19,656	14,379
1961	30,760	18,150	20,390	15,002
1962	31,623	19,021	20,934	15,613

Source: Commonwealth Statistician, *New South Wales Statistical Register,* Rural Industries and Settlement and Meteorology.
(a) Serviceable machinery only, in 1959 and later years.

APPENDIX III (a)

Regression Estimates for Old Wheat Regions, Calculated Using Intentions to Sow as Response Variable, and Using Separate Values of Prices

A. *DYNAMIC MODEL*

Region	Regression Coefficients			R^2
	Wheat Price	Wool Price	Lagged Acreage	
I	−0.103 (0.168)	−0.395 (0.139)	+1.002 (0.028)	0.88
II	−0.003 (0.142)	−0.364 (0.154)	+0.881 (0.201)	0.80
V	+0.040 (0.035)	−0.084 (0.031)	+0.644 (0.253)	0.80
VI	+0.037 (0.199)	−0.484 (0.221)	+0.835 (0.235)	0.76

B. *STATIC MODEL*

Region	Regression Coefficients		R^2
	Wheat Price	Wool Price	
I	+0.606 (0.143)	−0.528 (0.223)	0.61
II	+0.463 (0.149)	−0.443 (0.241)	0.46
V	+0.114 (0.023)	−0.088 (0.037)	0.68
VI	+0.507 (0.177)	−0.772 (0.288)	0.49

APPENDIX III (b)

Estimates Obtained from Actual Acreages for Old Established Wheat Growing Areas

A. *DYNAMIC MODEL*

Region	Regression Coefficients		Elasticity at the Mean		R^2
	$a_1\beta$	$(1 - \beta)$	Short-run	Long-run	
I	+0.127 (0.052)	+0.501 (0.171)	+0.505	+0.998	0.77
II	+0.107 (0.049)	+0.582 (0.183)	+0.398	+0.955	0.74
V	+0.024 (0.009)	+0.438 (0.178)	+0.336	+0.598	0.74
VI	+0.178 (0.090)	+0.262 (0.276)	+0.440	+0.596	0.60

B. *STATIC MODEL*

Region	Regression Coefficient a_1	Elasticity at the Mean	R^2
I	+0.224 (0.050)	+0.893	0.60
II	+0.195 (0.050)	+0.728	0.52
V	+0.037 (0.008)	+0.522	0.60
VI	+0.243 (0.057)	+0.600	0.57

APPENDIX III (c)

Regression Estimates for New Regions using intentions to sow as Response Variable

A. *DYNAMIC MODEL*

Region	Regression Coefficients		Elasticity at the Mean		R^2
	$a_1\beta$	$(1-\beta)$	Short-run	Long-run	
III	+0.046 (0.021)	+0.980 (0.127)	+0.159	+7.950	0.86
IV	+0.003 (0.004)	+1.206 (0.109)	+0.131	−0.013	0.92

B. *STATIC MODEL*

Region	Regression Coefficient a_1	Elasticity at the Mean	R^2
III	+0.075 (0.047)	+0.260	0.15
IV	+0.013 (0.086)	+0.662	0.09

APPENDIX III (d)

Estimates Obtained for Old Wheat Regions Calculated Using Intentions to Sow as Response Variable, and Price-Ratio Model: Liviatan's Estimator

Region	Regression Coefficients (a)		Elasticities at the Mean	
	$a_1\beta$	$(1-\beta)$	Short-run	Long-run
I	+0.112	+0.665	+0.409	+1.220
II	+0.102	+0.603	+0.354	+0.891
V	+0.024	+0.621	+0.303	+0.799
VI	+0.143	+0.560	+0.333	+0.757

(a) Standard deviations not estimated.