SUPPLY ANALYSIS FOR AUSTRALIAN AGRICULTURAL PRODUCTS WITH APPLICATIONS TO FARM AND NATIONAL INCOME ESTIMATION.

A thesis submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy.

by

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I give consent to this copy of my thesis, when deposited in the University Library, being available for loan and photocopying.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd) Page No.

TABLE OF CONTENTS (Cont'd) Page No.

LIST OF TABLES.

LIST OF TABLES (Cont'd) | Page No.

SUMMARY

The basic aim of this thesis is to develop an econometric model of the Australian farm sector and a major part of the thesis is devoted to this aim. The Introduction sets the stage by illustrating the lack of attention that has been paid to the farm sector by Australian econometric model builders. The Introduction also points out the emphasis on farm income and the "supply function" approach of this study. Chapter 2 discusses some methodological considerations and outlines some of the mathematical and statistical techniques that are used in the development of the model.

The next six chapters are devoted to estimation of the parameters of supply functions. In all, some twelve supply functions are specified and their parameters estimated. Between them they account for over 95 per cent of the value of all farm production. Chapter 8 develops functions for three different items of farm costs. Chapter 9 then brings together the supply functions, the cost functions and some identities which result in a complete model leading to the determination or explanation of farm income.

In Chapter 10, the model of the farm sector developed here is linked to a model of the Australian economy. The effects of the following simulations are then studied in terms of their effects on farm income and on G.N.P.; a fall in wheat prices, a drought, cost inflation and finally a fall in wool prices. The fall in wool prices is looked at under two different assumptions - (1) the fall only lasts for one year and (2) prices persist indefinitely at their new lower level.

The final section of the thesis is an Appendix containing data that were used in developing the model

This Thesis contains no material which has been accepted for the award of any other degree or diploma in any University; to the best of my knowledge and belief, this Thesis contains no material previously published or written by another person except where due reference is made in the text.

Signed: __________________________

Trevor J. Mules

CHAPTER 1

INTRODUCTION

The basic aim of this study is to develop an econometric model of the Australian farm sector. Econometric model building has a fairly short history in Australia, starting in 1962 with Nevile's elementary single equation model of the Australian economy.[1] Nevile treated the farm sector as exogenous, in particular, farm income was treated as a pre-determined variable. In 1966, Kmenta published a model of the Australian economy which was a mixed simultaneous and single equation system.[2] Kmenta explained farm income by making it a function of current exports and current agricultural terms of trade, both of which were exogenous. This approach also treats the farm sector itself as if it were exogenous, no attempt being made to quantify relationships within the sector.

In 1969, J. A. Zerby published a more complex simultaneous model of the Australian economy.[3] Considerably more attention was paid to the monetary sector than in the two previously cited studies and Zerby used three different estimating procedures and compared their results. However, farm income was still treated as a pre-determined

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1. Nevile, J.W., "A Simple Econometric Model of the Australian Economy", Australian Economic Papers, Vol.1, No.1, Sept. 1962, pp.79-94.

2. Kmenta, J., "An Econometric Model of Australia, 1948-61", Australian Economic Papers, Vol.5, No.2, Dec. 1966, pp.131-164.

3. Zerby, J.A., "An Econometric Model of Monetary Interaction in Australia", Australian Economic Papers, Vol.8, No.13, Dec.1969.

variable and no attempt was made to specify any functional relationships for the farm sector. In more recent times both the Reserve Bank of Australia and the Commonwealth Treasury have entered the field of econometric model building.[4] Both have developed fairly sophisticated quarterly models of the economy but both continue in the tradition of the earlier models of treating farm income as pre-determined and ignoring the functional relationships within the farm sector. This treatment is no doubt largely due to the fact that prices received by farmers are mainly determined by overseas trade conditions or are administratively determined and production of farm products is heavily influenced by weather conditions.

The treatment of the farm sector in the Australian models is to be contrasted with the treatment of the farm sector in a model of the U.S. economy. In the Brookings quarterly model of the United States, Fox develops quite a complex and far reaching sub-model of the U.S. farm sector.[5] In view of the relatively greater importance of agriculture to the Australian economy, the failure of model builders in this country to devote more attention to the farm sector is somewhat surprising.

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4. Norton, W.E. and Henderson, J.F., A Model of the Australian Economy - A Further Report, Reserve Bank of Australia, Occasional Paper No.3G, March 1972 and Higgins, C.I. and Fitzgerald, V.W., An Econometric Model of the Australian Economy, Commonwealth Treasury, Sept. 1972.

5. Fox, Karl A., "A Submodel of the Agricultural Sector", pp.409-464 in Duesenberry, James S., Fromm, Gary, Klein, Lawrence R., and Kuh, Edwin (eds.), The Brookings Quarterly Econometric Model of the United States, Rand McNally and Co., Chicago, 1965.

Historically, farm income and employment have been of major importance to the Australian economy and rural exports continue to account for over 50 per cent of total export receipts. Thus, the lack of a model of the farm sector is an important gap in our knowledge of the workings of the economy.

The purpose of this study is to attempt to fill that gap by specifying, and estimating the parameters of, an econometric model of the Australian farm sector. In particular, it is the purpose of this study to develop a set of functions which explain farm income, thus enabling a link to be established between this model and other models of the Australian economy. It was decided at the outset that the model should be an annual one, both because of greater data availability for an annual as opposed to a quarterly model and because most rural production activities occur on an annual basis, e.g. harvesting, shearing.

Because explanation of farm income is the ultimate aim and because, also, it is desired to look at the farm sector from a production viewpoint, the model is supply oriented, supply functions being a principal form of functional relationship with which to describe the sector. Chapter 2 gives details of the methodology of supply estimation that is employed.

For the most part, prices received for farm products are taken as pre-determined although some principal livestock product prices are explained. In total, some 96.5 per cent of the gross value of all rural production is explained by the supply functions. The remaining

3.5 per cent covers a number of individually minor products which were considered too small in term of total gross value to warrant a separate supply function.

Following the supply section, three items of farm costs are explained by functional relationships. A fourth, depreciation, is treated as pre-determined. No attempt is made to allocate farm costs on an industry basis because of the problem of joint costs. The level of disaggregation of farm costs is dictated largely by the availability of data. Farm income is found as a residual between gross value of rural production and total farm costs. This follows the procedure of the Commonwealth Statistician in arriving at his estimate of farm income. The Statistician's estimate, despite its shortcomings, is the one used in the econometric models of the Australian economy that have been published.

The data used in estimating the parameters of the supply and cost functions were almost wholly obtained from published sources of the Commonwealth Bureau of Census and Statistics (C.B.C.S.), the Bureau of Agricultural Economics (B.A.E.) and the Reserve Bank of Australia. A considerable amount of unpublished material on price indices was obtained from the B.A.E. The suitability and other characteristics of the data are discussed in the relevant sections below. Detailed tables of the data appear in the Appendix at the end of the study. For the most part, published data, or variables calculated from published data were found to be adequate. Thus the model has the advantage that its use is not limited to people or institutions with access to unpublished or generally unobtainable data.

The completion of the econometric model enables the effects of various stimuli on farm income to be studied, and from this the effects on Gross National Product can be obtained by linking the farm sector with a model of the economy using farm income as the link. Thus the effects of various rural policy considerations can be studied both in terms of their effects on farm income and in terms of their effects on the national economy. Of particular interest are the effects of cost inflation in the rest of the economy and of general drought on farm income and hence on G.N.P. In the final section on simulation, some arbitrary assumptions are made concerning simulated inflation and simulated drought. The assumptions do not differ greatly from some recent Australian experiences, however, and thus the effects studied may be used as a guide to the importance both to the farm sector and to the national economy of these particular phenomena.[6]

Australia has historically been regarded as being heavily dependent upon the wool industry. For this reason, wool auction prices are given considerable publicity and this has especially been so over the past few years when prices have suffered quite violent fluctuations. In the final section of this study, a wool price fall, comparable in magnitude to recent experience, is simulated and the effects on farm revenues, costs, income and ultimately Gross National Product are studied. These simulations do not purport to tell what will actually happen if wool prices fall, they merely use the model of

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6. In the case of inflation, the only effects on the national product which are quantified are those operating via the farm sector.

the farm sector that has been developed to describe the marginal effects of a wool price fall with all other exogenous variables held constant.

CHAPTER 2

THE METHOD AND TECHNIQUES USED IN SUPPLY ANALYSIS

General Approach

This study employs an ad hoc approach to agricultural supply analysis by considering each commodity or small group of commodities separately. This approach is to be contrasted with the work of Powell and Gruen[1] where an overall view of agriculture was used within the framework of a constant elasticity of transformation production frontier. The advantage of the Powell and Gruen approach is that it allows a consistent methodology to be applied to each sector. Its chief disadvantage is that it does not allow the incorporation of institutional factors which affect particular sectors in different ways. In addition, some serious questions have been raised concerning both the statistical characteristics of their results and the validity of using the unproven assumption of a constant elasticity of transformation to derive supply estimates which may have policy implications.[2]

The ad hoc approach of this study does not imply ignoring the possibility of production substitutes. Where considered relevant,

1. For a complete list of the relevant works see references to Watson, A.S., Harcourt, G.C. and Praetz, P.D. "The C.E.T. Production Frontier and Estimates of Supply Response in Australian Agriculture", Economic Record, Vol. 46, No.116, Dec. 1970, p.563.
2. See Watson, A.S., Harcourt, G.C. and Praetz, P.D., op.cit.

relative prices of the production substitutes were employed in a variety of formulations to reflect the competition for resources between commodities or groups of commodities. The sector or industry boundaries were defined either by data availability or by tradition. In some cases further disaggregation of a sector into smaller sectors was feasible but was decided against. For example data is available separately on each of barley, maize, oats and grain sorghum. However, in view of the smallness of each of them separately and because they are traditionally considered together under the heading "coarse grains" they were aggregated into one sector for supply analysis.

One feature of the ad hoc approach is that it allows the selection for each sector of a particular key variable that is considered to be of over-riding importance in farmers' production decisions. For each sector there are variables which are within the farmer's control and other variables which are largely weather determined. For example a wheat farmer can decide how many acres to plant to wheat on the basis of wheat prices and production costs and guesses about yields, but the actual quantity of wheat produced is predominantly determined by the quantity and timing of rainfall. This is evidenced by the variability in annual yield figures.[3] Hence for the wheat industry, acres planted to wheat can be thought of as being a key decision variable. The basic approach of this study is to identify such a variable for each sector and to use it as a dependent variable for regression analysis.

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3. See Table 1, p.31, below.

It might be argued that such an approach only explains one input in the production function (acres of land in the wheat industry) and that in order to explain or predict total output, other inputs such as labour, fertiliser, water, machinery, etc., should also be explained. All inputs could then be combined into a production function to obtain actual output. However, if the decision variable really is of overriding importance then the required quantity of other inputs will be automatically forthcoming. For example if the farmer decides to expand his wheat area but finds his capital equipment is not adequate, he will either replace the equipment or substitute labour for capital by working longer hours. Furthermore, it is a generally accepted view that in established areas of Australian agriculture factors of production tend to be combined in fixed proportions. National indicators such as the quantity of fertiliser used per acre would seem to discredit this but the national averages are affected by new land being brought in at the margin, usually with higher than average rates of fertiliser application. The decision variable approach is supported by the fact that rural spokesmen and observers use variables such as acres planted or livestock numbers to reflect production intentions of farmers, indicating that these decision variables are the true response or behavioural variables that reflect farmers' production intentions.

Sample Period and Data

As mentioned earlier, the model presented in this study is an annual one. The time period selected for study was from 1946-47 to 1968-69. The selection of 1946-47 as a starting point was influenced by a number of factors. First, published data for earlier years are generally less reliable and not as readily available as post-war data. Many statistical series were not begun by the Commonwealth Statistician or the B.A.E. until after the war and in others there are gaps and changes in definitions. Secondly, data for the war years are likely to be influenced by wartime conditions. They may therefore represent a different structure of supply response and one that is not relevant in peacetime.

The price data that were used were B.A.E. indices of prices received by farmers for various rural commodities. To allow for the fact that inflation in input prices has been eroding the 'real' value of commodity prices, the indices were deflated by the B.A.E. index of prices paid by farmers. Since the B.A.E. index of prices paid is highly correlated with the Consumer Price Index (correlation coefficient of 0.99), this deflation has the happy side effect of allowing for changes in farmers' living costs as well as changes in input costs. Use of the resultant 'real' prices involves two assumptions. First, it must be assumed that farmers are aware of the real value of the prices they receive and base their decisions on the real value rather than the nominal or money value. This assumption would seem to be fairly realistic in view of the publicity given to the cost-price squeeze on Australian agriculture. Second , use of the overall index of prices paid as a deflator involves assuming that costs in all sectors are being affected equally by inflation. This may not be true, but since indices of prices paid are not available on an industry basis, there appears to be no alternative to this assumption. In some sectors, when real prices did not perform well as explanatory variables, the possibility of a 'money-illusion' was tested by using the undeflated prices received indices.

All data other than price data were obtained from various publications of the Commonwealth Statistician. Detailed tables of data and sources are given in the appendix.

Shift Factors

Over the twenty three years used as the sample period for this study, it would be anticipated that various factors other than price have influenced agricultural supply, i.e. the classical price - supply relationship has been subject to a number of shift factors. In the rural sector, weather is a most obvious example of such a factor. There are a number of approaches to the problem of weather in agricultural supply analysis.

One approach is to attempt to modify or select a dependent variable such that it is free of weather influences. This is essentially the approach used by Powell and Gruen. Any predictions from such a model are therefore also weather-free and consequently some assumptions must be made about weather before the predictions can be related to reality. This is also characteristic of a second approach to weather. This approach allows a dependent variable which is weather-influenced but does not attempt to quantify the relationship. In other words, the effects of weather are assumed to be part of the disturbances in the regression equation. This approach may result in poor explanation in some cases.

The decision variable approach used in this study is in some instances an example of using a weather free dependent variable. For example, the number of acres planted to wheat is not likely to be influenced by weather in the current period to the same extent as production of wheat.[4] It may be influenced by a previous year's weather conditions if these were particularly bad or good. On the other hand, sheep numbers, while obviously an important decision variable, are likely to be influenced quite significantly by weather conditions some years in the past.

A third approach to weather concentrates on detailed measurements such as rainfall, temperature, sunshine, evaporation, etc. and attempts to quantify their effects either separately or together. This approach can yield fruitful results[5] but in view of the wide range and variability of weather over the whole of Australia it was considered to be an unsuitable approach to aggregate supply analysis.

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4. Extremely poor conditions at planting time would be expected to influence actual plantings. This consideration led Powell and Gruen to use a series of farmers' intended sowings as a weather free dependent variable. However, they founds the correlation between intended and actual sowings to be very high. This is possibly due to the fact that there have been relatively few years of extreme conditions at planting time in post-war Australia. See Powell, A.A. and Gruen, F.H., "Problems in Aggregate Agricultural Supply Analysis: I - The Construction of Time Series for Analysis", Review of Marketing and Agricultural Economics, Vol.34, No.3, Sept.1966, pp.114-117.
5. See Guise, J.W.B., "Factors Associated with the Variation in the Aggregate Average Yield of New Zealand Wheat, 1918-1967", American Journal of Agricultural Economics, Vol.51, No.4, Nov. 1969, pp.866-881.

A final approach seeks to find a variable which can be taken as a broad surrogate for the various effects of weather. In the grazing industries, this study employed an index of drought which was developed by Powell and Gruen. The index is obtained by calculating the annual crude mortality rate for the Australian sheep population and expressing each year's calculated rate as a deviation from the long term average rate. This index is henceforth referred to as the "drought mortality index". A high positive value of the index suggests generally unfavourable weather in the grazing industries.

In addition to weather, a number of other factors have acted to shift the supply curve in post-war-Australia. Such things as increased use of improved pasture, irrigation, fertiliser, mechanization and improved management techniques have acted to shift the supply curve outwards over time. These factors might all be lumped together under the general heading of "technology". A method which is sometimes employed in time series supply analysis is to include a time trend to take account of these various technical factors. Because this method does not specifically identify and then quantify the technical factors themselves, it involves assuming that they will always be present and will always be shifting supply outwards at the same steady pace. In order to avoid this problem, the approach taken in this study is to attempt to find at least one important technical shift factor and to then quantify its effects. Only in cases where it was impossible to identify such a factor was a time trend resorted to.

Distributed Lags

It is an honoured tradition in agricultural supply analysis to use or attempt to use the Koyck-Nerlove geometrically declining distributed lag model on prices. In such use it serves the dual purpose of reflecting both the mechanism by which producers' price expectations are believed to be formed and also the process of adjustment of supply to changing prices when for biological reasons this cannot be achieved in one year. In this study a truncated form of the geometric distributed lag was used. It was obtained by simply placing an arbitrary limit of n on the number of past years' prices that were relevant in arriving at current price expectations and in current supply adjustments. The form of the lag was as follows:

$$EP_t = \sum_{i=1}^{n} w^{i-1} P_{t-i}$$

where EP_t represents the index of price expected in year t, P_{t-i} is the price to which the formula is applied and w might be thought of as a coefficient of expectations.

If the formula is expanded for $n = 3$, we get:

$$EP_t = w^0 P_{t-1} + w^1 P_{t-2} + w^2 P_{t-3}$$

$$= P_{t-1} + wP_{t-2} + w^2 P_{t-3}$$

Thus in a regression equation, the coefficient on EP_t is also the estimated coefficient on P_{t-1}. This is formally equivalent to the Nerlovian case in which the effect of a price change is assumed to decline geometrically after one year.[6]

By iterating on different arbitrary values of w and n, different values of EP_t can be generated until the combination which gives the 'best fit'is located. The advantage of this approach is that it provides, by means of simple arithmetic, one variable to represent the distributed lag. This enables the inclusion in the supply model of other explanatory variables besides price, with their own distributed lags if required but without the messy algebra that is required to arrive at an estimating equation.. In the sections below, whenever this distributed lag formulation is used, it will be referred to as the truncated distributed lag (t.d.l.) model.

The t.d.l. formulation has a further advantage over the traditional distributed lag formulation. In the estimating equation which is derived from the traditional formulation, the lagged value of the dependent variable appears as an explanatory variable. Nerlove and Wallis have shown that when least squares regression is applied to such an estimating equation, the Durbin-Watson statistic may be automatically biassed in favour of non-rejection of the hypothesis of zero autocorrelation.[7] This

6. For an application of this assumption for the infinite distributed lag of Nerlove see Mules, T.J. and Jarrett, F.G., "Supply Responses in the South Australian Potato Industry", Australian Journal of Agricultural Economics, Vol.10, No.1, June 1966, p.55.

7. See Nerlove, Marc and Wallis, Kenneth F., "Use of the Durbin-Watson Statistic in Inappropriate Situations", Econometrica, Vol.34, No.1, Jan. 1966, pp.235-238.

situation does not arise when the t.d.l. is applied since it does not involve use of the lagged dependent variable as an explanator.

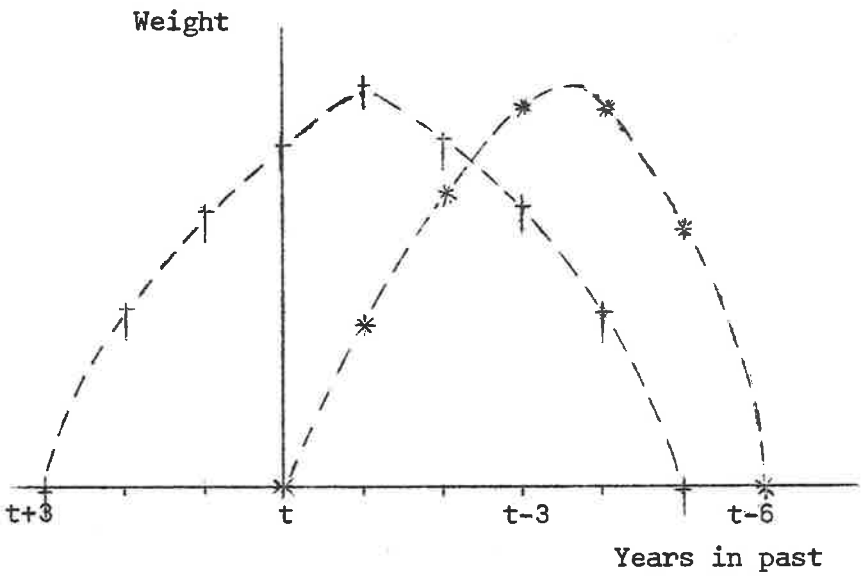
In recent applied econometric work, a new form of distributed lag has appeared and is attributable to Shirley Almon.[8] The Almon technique assumes that the weights on past data lie at discrete points on a polynomial instead of declining geometrically as is assumed in the Koyck-Nerlove case. Once the type of polynomial and length of lag are arbitrarily selected, Lagrangian multipliers are applied to past data in order to obtain a number of variables to be used as explanators. The number of such variables is always one less than the degree of the polynomial selected. Thus if a quadratic were selected, then there is only one such variable. The regression coefficients on these "Almon variables" are used in conjunction with the Lagrangian multipliers to obtain estimates of the actual weights for each year of the lag period which was arbitrarily decided upon.

An example of a quadratic pattern with a five year lag is illustrated by the asterisks in Figure 1. It can be seen that the weights are zero in both the current period and in the sixth year in the past (t-6). Another important feature of the pattern of weights is the fact that they have their maximum values in t-3 and t-4, declining symmetrically to either side of these years. Such a pattern of weights would seem to have useful application in agricultural supply analysis where biological constraints on aggregate supply adjustment may mean that current supply is more influenced by prices three and four years ago than by immediate past prices.

8. Almon, Shirley, "The Distributed Lag Between Capital Appropriations and Expenditures", Econometrica, Vol.33, No.1, Jan. 1965, pp.178-196.

FIGURE 1

Pattern of Weights for Quadratic Distributed Lag.



The daggers in Figure 1 illustrate the case where the weights on past data decline each year. Thus the same effect as the Koyck-Nerlove declining geometric weights may be achieved using the Almon technique by simply shifting forward the maximum point on the polynomial. In this case it is necessary to ignore the weights on current and future years but the method of estimating the weights remains the same. In this study a quadratic polynomial was used in every application of the Almon lag technique. The length of the lag and the placement of the maximum point of the quadratic will be specified in the relevant sections below.

Some Econometric Considerations

Because it is an annual model and in view of its *ad hoc* nature, this study is dominated by ordinary least squares (OLS) estimates of single equation parameters. The choice of annual data meant that for the cropping industries current period prices were not relevant in determining supply because of the length of the production period. Similarly, when explaining numbers of animals at the beginning of the year in the various livestock industries, current prices again could not be considered relevant. Thus in these instances the prices that were used were for past periods and were therefore pre-determined.

However, when animal slaughterings out of livestock numbers were being explained, it was considered desirable that current period prices be included as explanatory variables. Since Australia only exports, at the most, about half its total production of any carcass meat, these prices could not be regarded as being determined by foreign trade conditions and therefore could not be regarded as being determined independently of the number of animals slaughtered. This is a situation of simultaneous dependence and to allow equilibrium to be reached in each market, a demand equation for each type of livestock slaughtered was specified. The simultaneous estimation procedure of two stage least squares (2SLS) was used in these cases.

Application of OLS to the structural equations of a simultaneous model yields biassed and inconsistent, although still efficient estimates of structural coefficients. In the case of an exactly identified model, indirect least squares and 2SLS give identical results which are efficient and consistent. For over identified systems, both 2SLS and full information maximum likelihood (FIML) give consistent estimates. "Monte Carlo" studies reviewed by Johnston and

Goldberger[9] are somewhat conflicting in their conclusions regarding the choice between 2SLS and FIML based on their small sample properties, their large sample properties being identical. The selection of 2SLS in this study was ultimately one of convenience, there being a working 2SLS computer program available.

A problem that is often encountered in application of regression techniques to economic time series data is that of autocorrelated disturbances. The effects of applying ordinary least squares (OLS) formulae to models characterised by autocorrelation are described in detail in most modern econometric texts.[10] The estimated regression coefficients generally retain the properties of unbiassedness and consistency. However, the variances of the coefficients are affected in two ways. First, the sampling variances are larger than they need be and can be reduced by use of the autocorrelated structure. Second , OLS formulae underestimate these variances.

In this study, the test for the existence of autocorrelation was to compare the calculated value of the Durbin-Watson statistic with the critical values tabulated by Theil and Nagar.[11] When this test resulted in rejection of the null hypothesis of zero autocorrelation

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9. See Johnston, J., Econometric Methods, McGraw-Hill, 1963,pp.275-286 and Goldberger, A.S., Econometric Theory, John Wiley & Sons, Inc., 1964, pp.360-364.

10. See, for example, Johnston, J., op.cit., pp.177-200.

11. See Theil, H. and Nagar, A.L., "Testing the Independence of Regression Disturbances", Journal of the American Statistical Association, Vol. 56, Dec. 1961, p.802.

a method of estimation was used which was first suggested by Cochrane and Orcutt.[12] This method involves firstly assuming that the disturbances follow a first order auto-regressive scheme thus:

$$u_t = \rho u_{t-1} + E_t$$

where u_t is the disturbance for period t and E_t is a random disturbance. The coefficient ρ is known as the auto-correlation coefficient and in the case of positive auto-correlation (the most usual one in economics) it is assumed that $0 \leq \rho \leq 1$.

A first estimate of the value of ρ is obtained using a formula given by Theil and Nagar[13];

$$\rho = \frac{N^2(1 - \frac{1}{2}d) + k^2}{N^2 - k^2}$$

where N = number of observations,

d = calculated Durbin-Watson statistic,

k = number of coefficients estimated, including the constant term.

Each of the original variables (X_t) is then transformed to the form $X_t - \rho X_{t-1}$ using the estimated value of ρ. The regression is then re-run

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12. See Cochrane, D. and Orcutt, G.H., "Application of Least Squares Regression to Relationships Containing Autocorrelated Error Terms", Journal of the American Statistical Association, Vol.44, March 1949, pp. 53-59.

13. Theil, H. and Nagar, A.L., op.cit., p.804.

using the transformed variables, and, provided the assumption of a first order auto-regressive scheme is valid, the re-estimated equation is free of the effects of auto-correlation. It is a matter of simple algebra to show that the estimated regression coefficients on the transformed variables can be applied to the original variables in a predicting equation.[14] The estimated constant term in the transformed variable equation can be divided by $(1 - \rho)$ to form the appropriate constant in the predicting equation, which uses the original variables.

Hildreth and Lu suggest repeating the above transformation for different arbitrary values of ρ around the estimated value[15] and running the regression each time until that value of ρ is found which minimizes the sum of squared residuals. The coefficients estimated from the regression using that particular value of ρ are then selected as being the most efficient estimates of the coefficients of the original model. Kmenta has suggested that to complete the picture a new squared coefficient of determination (R^2) should be calculated using the new regression coefficients and the original data.[16] Both the Hildreth-Lu and the Kmenta suggestions are incorporated into the attacks made on auto-correlation in this study. The steps in the procedure may be summarised as follows:

1. Obtain a first estimate of ρ using the Durbin-Watson statistic.
2. Transform the original variables (X_t) to the form $X_t - \rho X_{t-1}$ for arbitrary values of ρ around the first estimate.
3. Re-run the regression on each set of transformed data, calculating

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14. See Johnston, J., op.cit., p.196.
15. Hildreth, C. and Lu, J.Y., Demand Relations with Autocorrelated Disturbances, Technical Bulletin No. 276, Agricultural Experiment Station, Michigan State University, 1960.
16. Kmenta, J., Elements of Econometrics, Macmillan, New York, 1971, p.287.

the sum of squared residuals each time.

4. Select that value of ρ, and its associated regression coefficients, which minimizes the sum of squared residuals.

5. Calculate the constant term for the original equation and calculate R^2 using the new regression coefficients applied to the original data.

Where this procedure is used in the sections that follow, it will, for convenience be referred to as the Hildreth-Lu procedure. It should be noted, finally, that in simultaneous equation systems, little is known of the effects of autocorrelation or of the Hildreth-Lu procedure. The procedure was therefore not applied in these circumstances.

CHAPTER 3

SUPPLY FUNCTIONS FOR WHEAT AND COARSE GRAINS

WHEAT

Introduction

Very little attention has been paid to investigating factors which affect the wheat supply in Australia. While useful in itself, the Duloy-Watson[1] study was far too localised to be of relevance for predictions at the national level. The Powell and Gruen study,[2] while taking a national viewpoint, avoided the issue somewhat by basing their dependent variable on a series of growers intended sowings of wheat rather than actual sowings.[3] This choice is based on the apparently reasonable premise that actual sowings are affected by "last minute" weather conditions and that intended sowings more accurately represent growers' assessment of the economic and technical conditions of wheat growing. Accordingly, the intended sowings series should lend itself more readily to explanation and prediction by a model which incorporates the relevant economic and technical factors. While the present writer can see the sense of this "weather-free" approach, he does not believe that the

1. Duloy, J.H. and Watson, A.S., "Supply Relationships in the Australian Wheat Industry: New South Wales", Aust. Journal of Agricultural Economics, Vol.8, No.4, June 1964, pp.28-45.

2. Powell, A.A. and Gruen, F.H., "Problems in Aggregate Agricultural Supply Analysis: I - The Construction of Time Series for Analysis", op.cit., pp.112-135.

3. The correlation between intended and actual sowings was very high at 0.99, indicating that Powell and Gruen could have equally well used the actual figures. It is not so much what they did that is criticised as what they did not do.

series of actual acreage has shown so much instability due to weather that a reasonable explanatory and predictive model cannot be found for it.

It is significant that in both studies cited, acreage is used as the dependent variable rather than production. Actual production, as demonstrated by the yield per acre series in Table 1, is heavily influenced by weather conditions throughout the crop year. Clearly then, if the intention is to develop a model which describes wheat-growers' production behaviour, acreage is a far better choice than actual output since it is acreage over which growers have the most discretion and over which production decisions are most likely to be made.

Fig. 2 depicts the movement of the aggregate wheat acreage over the period 1946-47 to 1968-69. The relative smoothness of the graph suggests that weather vagaries have little impact on sowings, although the dip in 1956-57 is due to a particularly wet sowing season, as is the levelling off of acreage in 1963-64. The dip in 1965-66 is due to a very dry sowing season. The droughts of 1957-58 and 1967-68 seem to have had little effect,other than to temporarily reduce the rate of growth of acreage, and even then, only slightly. Apart from these instances, the overall smoothness of the graph suggests that some underlying economic and technical factors are responsible for the broad changes that have occurred. In view of the importance of the wheat-sheep mix in Australian agriculture, the ratio of the wheat price to wool price must be considered as an important economic factor.

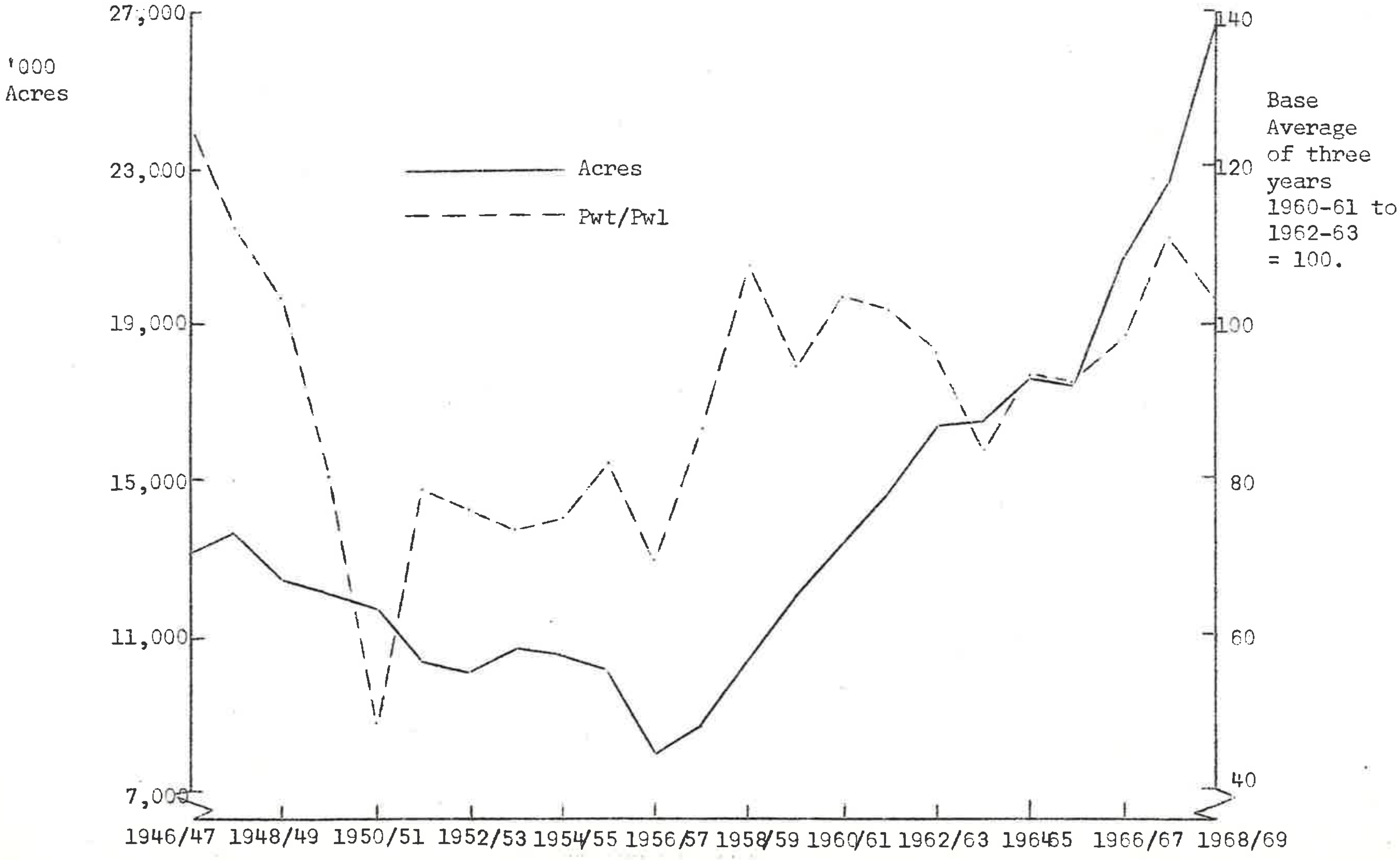
FIGURE 2

TOTAL WHEAT ACREAGE AUSTRALIA - 1946-47 to 1968-69

FIGURE 3

TOTAL WHEAT ACREAGE AND RATIO OF WHEAT TO WOOL PRICES AUSTRALIA

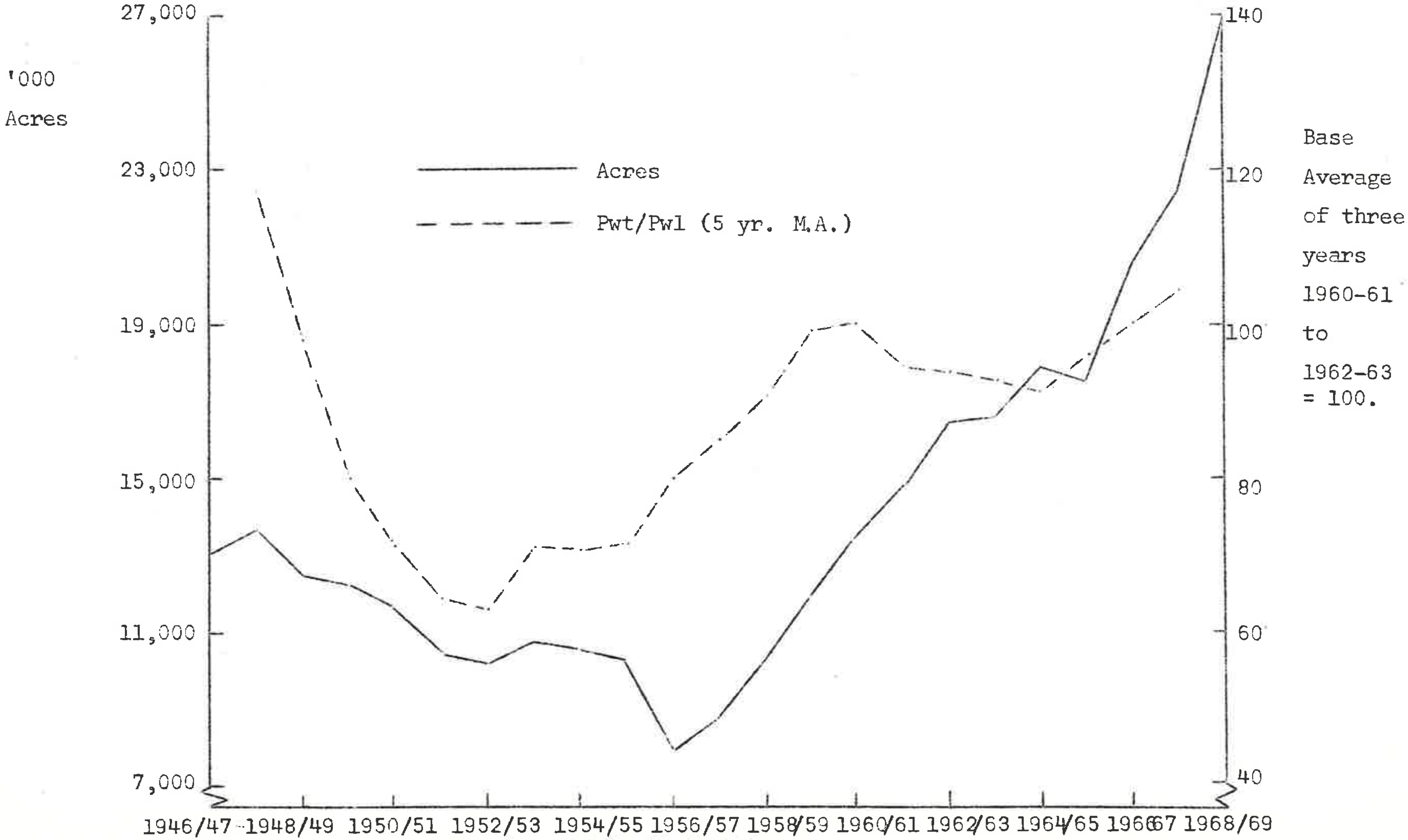
1946-47 to 1968-69.



Source: C.B.C.S., Rural Industries Bulletin, various issues and material supplied by B.A.E.

FIGURE 4

Total Wheat Acreage and Five Year Moving Average of Ratio of Wheat to Wool Prices Australia - 1946-47 to 1968-69.



Source: C.B.C.S., Rural Industries Bulletin, various issues and material supplied by B.A.E.

Fig. 3 depicts the ratio of wheat price to wool price, super-imposed on a graph of wheat acreage. The prices are B.A.E. indices of prices received for wheat and wool. In their raw form the prices are too unstable to explain the steady movements in wheat acreages. However, in Fig. 4, a centred five year moving average of the ratio is graphed against wheat acreages and a remarkable similarity between the two patterns emerges. This is particularly so if a lag of three or four years is allowed. This seems to indicate quite clearly that the relative prices of wool and wheat are important economic factors determining wheat acreages.

The important technical factors affecting wheat acreages over the period being studied are the introduction of legumes in rotation with the wheat crop,[4] the use of fertiliser, and the development of new varieties of wheat Fertiliser usage would appear to hold the key to technical change, being an important catalyst in the effects of the other two factors. The effect of introducing legumes into the soil is to cause the nitrogen content of the soil to rise. The yield increasing properties of this nitrogen are magnified by the application of superphosphate, which is overwhelmingly the most important artificial fertiliser used on the wheat crop. Similarly, to the extent that new varieties of wheat have been important, their effect on yields is also magnified by increased soil nitrogen and application of "super". There is even some suggestion[5] that some new varieties have been or are

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4. This is discussed in Donald, C.M., "The Progress of Australian Agriculture and the Role of Pastures in Environmental Change", Aust. Journal of Science, Vol.27, No.7, 1965, p.19.

5. See Donald, C.M., op.cit., p.195.

being bred specifically for use with the increased input of nitrogen and phosphate.

The combined effect of these developments does not appear to have raised overall national yield per acre but rather has made it profitable to clear and sow land to wheat which was previously at the margin of profitability and productivity. From Table 1 it can be seen that not only was there no clear trend in wheat yield over the period but also, the yield was quite unstable. This instability was no doubt due to seasonal conditions during growing and/or harvesting and illustrates the logic of using acres as a dependent variable rather than production.

Also worth noting from Table 1 is the sustained increase in fertiliser usage[6] from 1960-61 onwards. This is during the period when wheat acreage was increasing from year to year almost without check. From this circumstantial evidence and from the fact that fertiliser holds the key to other technical factors, it was decided that fertiliser use per acre should be used to represent the effects of technology on wheat acreages. The case for this is strengthenedd by the fact that an important source of increased acreages during the 1960's was hitherto pastoral land with soil enriched by nitrogen from leguminous pasture.

Thus far it is clear that the prices of wheat and wool and the usage of fertiliser per acre are important explanators of wheat acreage. On *a priori* grounds it might be expected that the prices

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6. Fertiliser usage or fertiliser per acre refers to the quantity of artificial fertiliser used on the wheat crop divided by the number of acres fertilised.

of other grains relative to the wheat price would be important in determining shifts of land between production of wheat and production of other grains. However, in the regression results reported below, little evidence is found to support this. Possibly such shifts of this nature that do occur are insignificant, either in relation to total wheat acreages or in relation to shifts in wheat acreages due to other factors.

The Development of a Model

In the initial stages of developing a model to explain wheat acreage a great many related factors were envisaged as being important. In addition to the prices of wheat, wool and other grains and the usage of fertiliser, there was the problem of how to specify the effects of these variables in a model. For example, was the relevant specificatic for fertiliser usage that pertaining to the current period, the last period, the average of the past n periods or the trend value for the current period? Such questions were often resolved by running trial regressions and examining the results in comparison with the results of an alternative specification. In the discussion that follows, some of the possible specifications are examined and reasons for their rejection are given.

First, on the question of fertiliser usage, the current period specification was rejected on the grounds that fertiliser usage was supposed to represent the effects of technology on sowings.

TABLE 1

Details of Australian Wheat Production:

1946-47 to 1968-69

Year	Acres Planted ('000)	Production ('000 bushels)	Yield (Bushels /acre)	Fertiliser[1] per Acre (lb.)	Price[2]	Price[3] Ratio
1946-47	13,179.6	117,262.1	8.9	71.56	59	
1947-48	13,880.3	220,116.3	15.9	78.51	83	118
1948-49	12,583.5	190,702.6	15.2	84.27	91	93
1949-50	12,240.3	218,221.1	17.8	93.30	87	81
1950-51	11,663.2	134,244.4	15.8	87.77	93	72
1951-52	10,383.7	159,725.1	15.4	88.16	98	65
1952-53	10,209.5	195,207.9	19.1	89.98	107	63
1953-54	10,750.9	197,960.5	18.4	87.85	99	72
1954-55	10,672.6	168,616.5	15.8	90.66	89	69
1955-56	10,166.0	195,443.5	19.2	89.32	89	72
1956-57	7,874.6	134,454.6	17.1	91.88	91	80
1957-58	8,847.8	97,566.3	11.0	90.79	94	85
1958-59	10,399.2	215,120.6	20.7	89.31	96	90
1959-60	12,172.4	198,500.9	16.3	88.55	98	98
1960-61	13,438.9	273,716.1	20.4	88.16	99	101
1961-62	14,722.7	247,177.8	16.8	90.50	101	95
1962-63	16,468.6	306,911.8	18.6	92.29	102	95
1963-64	16,473.5	327,912.2	19.9	94.79	99	92
1964-65	17,918.6	368,788.7	20.6	98.32	97	91
1965-66	17,514.6	259.665.6	14.8	102.34	99	95
1966-67	20,822.8	466,610.0	22.4	105.49	102	100
1967-68	22,441.0	277,288.8	12.4	109.53	105	104
1968-69	26,799.5	543,950.0	20.3	111.87	102	

(1) Defined in footnote above.

(2) B.A.E. index of price received for wheat, base 1960-61 to 1962-63 = 100.

(3) Centred five year moving average of ratio of B.A.E. index of wheat price to B.A.E. index of wool price.

Accordingly, the latest technology available to growers at the time of planting the crop for year t is represented by fertiliser usage in t - 1. The trend value of fertiliser usage was rejected on the grounds that a time trend for fertiliser per acre was unrealistic for the years prior to the 1960's when fertiliser usage and therefore technology was reasonably stable. Since the data on fertiliser usage per acre are only available back to 1943-44, and since the sample period throughout was 1946-47 to 1968-69, the longest possible term for a moving average of the past n years fertiliser usage was 3 years. It was found that this did not smoothe the series significantly and regressions in which this specification was used gave results which were statistically no different from specifications in which a simple one year lag (i.e. fertiliser usage in t-1) were used. Hence, in the interests of simplicity, the latter specification was decided upon.

Second , the operation of the wheat stabilisation scheme[7] made the specification of the wheat price something of a problem. In recent years, growers have been receiving approximately 80 per cent of the equalised price very soon after delivery of their grain to the Wheat Board terminal. The balance is normally received within two years depending upon the Board's success at negotiating export sales. However, in the late 1940's and for much of the 1950's, the initial payment was considerably smaller, sometimes as low as 50 per cent and the final payment was not made until three or even four years later.

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7. For a description of the operation of the scheme see Bureau of Agricultural Economics, Rural Industry in Australia, Canberra, 1966, pp.73-75.

In a situation such as this there are at least two possible approaches to formulating growers' price expectations. One is to assume that growers act wholly on the basis of the first advance, i.e. that subsequent expected payments are heavily discounted to zero. This is perhaps more realistic in later years where the first payment has been such a large proportion of the equalised price. The other approach assumes that growers guess at what the final equalised price will be on the basis of payments received up to a certain point. This is essentially the approach used by Powell and Gruen[8] and is also basically the method of estimation used by the Bureau of Agricultural Economics in deriving its index of prices received for wheat. With experience and knowledge of the industry, an estimate which is very close to the final price may be obtained.

A further problem in relation to the specification of price is how to take account of the relative attractiveness of the wheat and wool prices and the wheat and other grains prices. In an attempt to resolve both this puzzle and the above problem of which wheat price to use, some trial regressions were run to enable comparisons to be made of different specifications. For the wheat price, two specifications were tried:

(a) the B.A.E. index of prices received for wheat, lagged one year and deflated by the B.A.E. index of prices paid by farmers,

(b) the first advance payment most recently known to growers at the time of planting, converted to an index and deflated by the B.A.E. index of prices paid.

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8. See Powell, A.A. and Gruen, F.H., op.cit., pp.117-124.

Two specifications were also used to take account of the prices of competing products:

(a) the lagged, deflated price index of each product, specified as a separate variable. This approach did not result in the problems of multicollinearity that might be expected since the correlation coefficients between most of the price variables were fairly low. The wool/wheat coefficient was 0.54, the first advance/wool was -0.23. The highest was wheat/other grains at 0.86.

(b) the ratio of wheat price to price of competing product, lagged one year. Strictly speaking, both numerator and denominator of the ratios should be deflated by cost indices for the relevant product. However, since only one cost index is available for Australian agriculture, namely the B.A.E. index of prices paid, it is necessary to assume that cost changes have been equal for all industries. This would result in having the B.A.E. cost index in both the numerator and the denominator of the ratios and it thus cancels itself out.

In all regressions tried, fertiliser usage per acre lagged one year was used to represent technology. In the regressions in which various combinations of the lagged, deflated price index for each product were tried, the degree of explanation was poor (R^2 ranged from 0.24 to 0.61). The B.A.E. wheat price coefficient was generally positive and significant at 5 per cent and the B.A.E. wool price coefficient was generally negative (as expected) and significant. The B.A.E. price index for other grains never achieved significance at 5 per cent and generally had an unanticipated positive sign. Both of these effects are possibly attributable to multicollinearity. In all regressions in which the deflated index of the first advance appeared, its coefficient was negative. In all models, the hypothesis of zero autocorrelation was rejected at both five per cent and one per cent using the Theil-Nagar test.

The regressions in which price ratios appeared also had generally poor explanation. The highest R^2 was 0.77 and was obtained for the equation which used the ratio of B.A.E. wheat to wool price indices, lagged one year and of course lagged fertiliser usage. Generally speaking, the coefficients on all price ratios had the sign that would have been expected. The exception was the ratio of first advance to prices of other grains which had a negative coefficient. All ratios involving prices of other grains failed to achieve significance at 5 per cent. This result, combined with the above result of unexpected positive sign on the deflated, lagged index for prices of other grains led to the conclusion that the competition for land from other grains was not important to the wheat industry. This conclusion is confirmed by the discovery by Powell and Gruen of a partial transformation elasticity between the two enterprises which was not significant at five per cent.[9]

The coefficients on both the ratio of B.A.E. wheat to wool price indices and the ratio of first advance to wool price indices had the expected positive sign and both were significant at one per cent.

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9. See Gruen, F.H. and others, Long Term Projections of Agricultural Supply and Demand, Australia 1965 to 1980, Dept. of Economics, Monash University, 1967,pp.6-37.

The choice between these was made on the basis of the degree of explanation of the whole regression. For the former, R^2 was 0.77, as mentioned above, for the latter it was 0.52. Thus the ratio of B.A.E. wheat to wool price indices was chosen to represent the economic factors affecting wheat acreage. As pointed out above in a comparison of Figures 3 and 4, if the series of wheat to wool price ratio is smoothed by some process it bears a much closer resemblance to wheat acreage and therefore a smoothed series is likely to provide a higher R^2 than 0.77 when used in a regression equation.

It seems quite reasonable that growers would smooth the erratic shocks out of the series when examining the relative attractiveness of the two enterprises. However, it is impractical to allow farmers the ability to see three years into the future and to use the centred five year moving average of the ratio from Fig. 4 as an explanatory variable. Accordingly, the t.d.l. was applied to the price ratio in order to smoothe it. As discussed above in Chapter 2, this provides an index of expected price, or in this case, of the price ratio.

Values of the index of the expected price ratio were generated for values of ω of 0.3, 0.5, 0.7 and 1.0 and for values of n of 3 years and 5 years. A regression was run using the expected ratio as defined by each combination of ω and n, and with fertiliser usage in each equation. The coefficients on both variables were significant at the one per cent level in every case, the highest R^2 being obtained when $\omega = 0.3$ and $n = 3$. The estimated coefficients for this case were:

$$WTA_t = -39{,}308 + \underset{(51.8)}{425^{**}} WFU_{t-1} + \underset{(15.8)}{117^{**}} \dot{E}(Pwt/Pwl)_t \quad \ldots\ldots\ldots\ldots \quad \text{(i)}$$

$$R^2 = 0.78$$

$$D\text{-}W = 1.62$$

WTA_t = total wheat acreage in period t.

WFU_{t-1} = fertiliser usage on the wheat crop in year t-1, as defined above.

$E(Pwt/Pwl)_t$ = index of expected price ratio, as defined above with $\omega = 0.3$, $n = 3$.

Following the usual practice, the standard errors are given in parentheses beneath the coefficients. One asterisk indicates significance at five per cent, two asterisks indicate significance at one per cent. The Durbin-Watson statistic is sufficiently high to enable the non-rejection of the hypothesis of zero autocorrelation. The degree of explanation (78 per cent), while reasonable, is not as high as was hoped. There are two main reasons for this:

(a) None of the distributed lag formulations imparted the same smoothness to the series of the wheat/wool price ratio as the centred five year moving average. This is true even of the formulation in which $\omega = 1.0$ and $n = 5$ which is different from a moving average of the <u>past</u> five years only by a scale factor of five. Nevertheless, the distributed lag formulation is considered worth retaining in view of the significance of the coefficients and its superior performance. in terms of the Durbin-Watson (D-W) statistic, over the model in which a simple one year lagged value of the price ratio was used. In this latter model, the D-W statistic was 1.37 indicating the presence of positive autocorrelation.

(b) Inspection of the residuals of the estimated equation showed some very large negative residuals and one very large positive residual occurring in the 1940's and 1950's. These residuals were found to be associated with large upswings in the value of the fertiliser variable for negative residuals and a large downward movement in the case of the positive residual. This indicates that the coefficient on this variable is tending to over-predict in the early years on the occasions when fertiliser usage exhibited significant variability.

As can be seen from Table 1, fertiliser usage did not exhibit any clear trend until the 1960's. Furthermore, if technical change in the form of new varieties and wheat/legumes rotation was occurring in this early period, it was certainly not having any clear-cut effect on acreage or production (Table 1). The downward movement in acreage was quite clearly motivated by the greater profitability of wool as opposed to wheat growing. It seems likely that the effects of technology were held in abeyance until relative prices swung in favour of wheat growing in the late 1950's. Accordingly, it was felt that the technology surrogate should have a constant value through to 1958-59[10] and

10. This is the year which is generally accepted by observers as being the take-off point for the boom in Australian wheat acreage in the 1960's. The increase in acreage for this year of around 1.5 million acres was the largest annual increase in acreage since 1946-47.

thereafter should be reflected by the fertiliser usage variable. The constant value which was assigned to technology during this period was the average value of fertiliser usage over the period 1946-47 to 1957-58.

With the technology surrogate thus modified, the regression was re-run with the modified variable replacing WFU_{t-1}. The results of this regression are as follows:

$$WTA_t = -47{,}744 + \underset{(45.7)}{628^{**}} MTW_{t-1} + \underset{(8.7)}{35^{**}} E(Pwt/Pwl)_t \qquad \ldots\ldots \text{(ii)}$$

$$R^2 = 0.91$$

$$D\text{-}W = 0.87$$

where WTA_t and E(Pwt/Pwl) are as defined for equation (i) and MTW is the modified technology variable, as defined above. Both regression coefficients are significant at one per cent and the degree of explanation (91 per cent) is considerably improved. However, the Durbin-Watson statistic is in the region of rejection of the hypothesis of zero autocorrelation and indicates positive autocorrelation to be present.[11]

On the assumption that the autoregressive system is a first order Markov process, the value of ρ was calculated to be 0.59, using the Theil-Nagar formula given in Chapter 2 above. The Hildreth-Lu procedure was then applied for values of ρ of 0.50, 0.55, 0.60, 0.65 and 0.70. As can be seen from Table 2, the minimum sum of squared

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11. For a discussion of the validity of the use of the Durbin-Watson statistic in testing for autocorrelated disturbances in equations (i) and (ii) see the Appendix at the end of this section.

residuals was obtained for $\rho = 0.6$ which is almost exactly the original estimate of 0.59.

TABLE 2

ρ	Sum of Squared Residuals
0.50	0.25923×10^8
0.55	0.25922×10^8
0.60	0.25913×10^8
0.65	0.26117×10^8
0.70	0.26470×10^8

The coefficients obtained for $\rho = 0.6$ gives the following equation in terms of the original variables.

$$WTA_t = -44{,}225 + \underset{(76.1)}{591}^{**} MTW_{t-1} + \underset{(16.2)}{36}^{*} E(Pwt/Pwl)_t \quad \ldots\ldots \text{(iii)}$$

$$R^2 = 0.91$$

$$D\text{-}W = 2.02$$

The D-W statistic indicates that this regression is free of the effects of autocorrelation. The R^2 was calculated by using the regression coefficients as estimated for $\rho = 0.6$ and generating a set of predicted values for the dependent variable. These were then compared to the actual values to see what degree of explanation was obtained. The coefficient on the technology variable (MTW) is significant at one per cent, the coefficient on the expected price ratio is significant at five per cent.

The coefficient on the price variable deserves some further attention. It should be noted that it is virtually the same as the coefficient obtained in equation (ii), before the application of the Hildreth-Lu procedure. However, it is much different, about one third the size in fact, from the coefficient of 117 which was obtained in equation (i). In this latter equation, technology was represented by the unmodified fertiliser usage, lagged one period. The question which presents itself is which coefficient on the price variable (and therefore which regression equation) is to be preferred and why?

A first answer to this question would point to the considerably higher R^2 for equations (ii) and (iii). All estimates of the coefficients do, after all, have the property of unbiassedness, even where autocorrelation is evident as in equation (ii). However, it might be counter-argued that the higher R^2 in these equations is a result of manipulating the technology variable. In order to resolve this issue, the short run (one year) and long run (three year) price elasticities of supply were calculated at average levels of all variables for the two possible price coefficients. These were compared to the price elasticities obtained in the Duloy-Watson study and the Powell-Gruen study. The comparisons are shown in Table 3. The range of estimates for the Duloy- Watson model refers to different wheat growing regions in N.S.W., while the range for Powell and Gruen refers to different models.

TABLE 3

Comparison of Price Elasticities of Supply.

Source	Short Run	Long Run
Equation (i)	0.78	1.09
Equation (iii)	0.21	0.30
Duloy-Watson	0.13 - 0.51	-0.01 - 7.97
Powell-Gruen	0.09 - 0.19	0.70 - 0.88

The Duloy-Watson long run estimates have too wide a range to be considered useful and since they are calculated for the Nerlovian infinite supply response, they are not comparable with the three year response of equations (i) and (iii).

Ignoring the Duloy-Watson long run estimates, it can be seen that both long and short run elasticities obtained from equation (i) are considerably higher than the estimates obtained from the studies cited. The short run elasticity from equation (iii) is close to that obtained by Powell and Gruen for their three sector model (0.19) but is somewhat higher than that obtained for their two sector model (0.09 - 0.15).[12] It is near the middle of the range of estimates made by Duloy and Watson. The long run elasticities of Powell and Gruen are calculated for a five year response period and this is partly why they

12. These estimates are to be found in Powell, A.A. and Gruen, F.H., "Problems in Aggregate Agricultural Supply Analysis: II - Preliminary Results for Cereals and Wool", Rev. of Marketing and Agricultural Economics, Vol.34, No.3, Dec. 1966, pp.195-200.

exceed the long run estimate of equation (iii) which is for only three years. When this is taken into consideration, the Powell and Gruen result is somewhere in between the estimates provided by equations (i) and (iii) giving no clear-cut indication of which is to be preferred.

On balance, it is felt that the estimated coefficients of equation (iii) are to be preferred to those of equation (i). Neither the short nor long run elasticities obtained from equation (iii) are seriously challenged by either the Duloy-Watson or Powell-Gruen results whereas the short run elasticity obtained from equation (i) does seem to be too high in comparison. Thus equation (iii) was selected as the supply equation for wheat acreage to be used in the final model. The question that perhaps remains is in what way this equation is superior to Powell and Gruen's model.

In terms of R^2 and statistical significance of coefficients there is little to choose between them. One advantage of the function presented here is that it explains actual acreages rather than the series of farmers' intended sowings and thus provides a direct link to actual production and thereby to farm income. Another advantage of the approach herein is that it avoids the necessity of making Powell and Gruen's inflexible assumptions about elasticities of transformation. Finally, by using a modified series of fertiliser usage, this study has uncovered a catch-all which is, at least up to the present time, useful in representing the shift-factors affecting the supply curve. By using the lagged value of the dependent variable to achieve this, Powell and Gruen really avoided the issue of what were the actual technical factors involved and how they affected national acreage.

A qualification that must be made to the function of equation (iii) concerns the introduction of quotas on the Australian wheat industry in 1969-70. The quotas are imposed on deliveries to the Australian Wheat Board and since at the time of writing they have only been in effect for four years, there are insufficient observations to quantify their effects on wheat acreages using regression analysis. Should the quotas continue to be used as an instrument of rural policy, the model presented herein will need to be revised when sufficient observations are available to quantify their effects. In the meantime, any forecasts using the model will need to take account of the likely effects of the quotas. It seems to be generally agreed that reduced quotas are causing reduced acreages[13] but the nature of the leads and lags involved can only be speculated on at this stage.

13. See Bureau of Agricultural Economics, The Coarse Grains Situation, No. 16, Canberra, Nov. 1971, p.14.

APPENDIX ON THE USE OF THE DURBIN-WATSON STATISTIC

The test for autocorrelated disturbances that was applied to the equations (i), (ii) and (iii) involved comparing the calculated Durbin-Watson statistic to the critical values tabulated by Theil and Nagar. Nerlove and Wallis[1] have shown that the D-W statistic is biassed in favor of accepting the null hypothesis when the lagged dependent variable is used as an explanatory variable. Their case depends on the coefficient on the lagged dependent variable being non-zero. It might be thought that the technology variables WFU_{t-1} and MTW_{t-1} in equations (i) and (iii) respectively would be nominally equivalent to having the lagged dependent variable as an explanatory variable <u>if</u> the correlation between the technology variables and WTA_{t-1} (the lagged dependent variable) was high.

For the case of equation (i), the squared correlation coefficient between WFU_{t-1} and WTA_{t-1} was only 0.2 which appears to be too low to cause any annoyance. For equations (ii) and (iii), the squared correlation coefficient between MTW_{t-1} and WTA_{t-1} was 0.7 which is possibly high enough to cause some consternation. Unfortunately due to the small number of observations it is not possible to use Durbin's large sample test for bias in the D-W statistic.[2] The test is extremely sensitive to sample size, small samples almost automatically leading to the conclusion of unbiassedness.

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1. Nerlove, Marc and Wallis, Kenneth F., <u>op.cit.</u>.
2. See Durbin, J., "Testing for Serial Correlation in Least Squares Regression When Some of the Regressors are Lagged Dependent Variables", <u>Econometrica</u>, Vol. 38, No.3, May 1970, pp.410-421.

In the face of such inconclusiveness as to how appropriate the D-W statistic is in such circumstances, all that can be done is to at least use it as a guide in stepping from equation (ii) to equation (iii) We have the comforting thought that the estimated coefficients are at least unbiassed. Any conclusion regarding their efficiency may have to wait until the small sample properties of Durbin's test are investigated.

NOTE:
The print copy of this thesis held in the University of Adelaide Library does not include page 47.

COARSE GRAINS

Introduction

The term "Coarse Grains" refers to barley, maize, oats and grain sorghum. In terms of value of production, barley and oats are by far the most important, accounting for over three quarters of the total. Acreage and value of production of grain sorghum have tended to increase fairly steadily during the 1960's, whilst production and acreage of maize have stayed fairly constant. The coarse grains sector is about the same size as the fruit industry or about one quarter of the size of the wheat industry when measured in terms of gross value of production. It is usual for the four grains to be considered under one heading, both because individually they are not very significant in value and also because there tends to be a high degree of substitutability between them, both in production and in their principal use as stock feed.

Because of the obvious similarity between the coarse grains industry and the wheat industry, the approach in formulating a supply model for the former follows similar lines to those pursued in developing a wheat supply function. First, it was arbitrarily decided to use coarse grains acreage as dependent variable for the same reasons as those given for adopting wheat acreage as the dependent variable in the wheat supply model. Second, as Fig. 5 shows, a coarse grains acreage has shown a fairly strong upward trend over the period being studied. The variations around the trend appear more marked than they were for wheat acreage. These variations may be due to economic factors, seasonal factors or both.

The Supply Model

It seems fairly likely from an inspection of Fig. 5 that some shift factor or factors are operating on the supply curve for coarse grains. For the wheat model, fertiliser usage was identified as being an important catch-all for the shift factors operating on the supply curve, at least during the second half of the sample period. Data on fertiliser usage on coarse grains crops is only available for the last ten years of the sample period, however from the data for this ten year period it is apparent that fertiliser used and area fertilised for coarse grains accounts for over eighty per cent of fertiliser used and area fertilised for the C.B.C.S. earlier classification "other crops" Thus it is felt that movements in fertiliser usage for other crops could be used to represent movements in fertiliser usage on coarse grains.

It was thought *a priori* that fertiliser usage on coarse grains would operate in the same way as fertiliser usage on the wheat crop. The increase in soil nitrogen brought about by the introduction of leguminous pasture would be expected to have the same beneficial effects on coarse grains productivity as it did on wheat productivity and should be equally as sensitive to application of superphosphate in its effect for coarse grains as it was for wheat. However, for the two major grains, barley and oats, there has been no clear trend in yields per acre over the period and furthermore there has been no trend evident in the fertiliser usage per acre on "other crops". It is for this reason that the coefficient of correlation between area under coarse grains and fertiliser usage on "other crops", lagged one period, is only 0.5. Because of this low correlation, the fertiliser usage variable does not adequately explain the shifts in the supply curve and negative coefficients are obtained on various price variables that were tried.

One possible explanation of the failure of fertiliser usage as a shift variable is that there has been a learning process going on, i.e. that time itself is the shift variable. As Fig. 5 shows the period of most pronounced upward movement in coarse grains acreage was prior to the late 1950's. It seems possible that during this period Australian farmers were involved in a learning process concerning coarse grains, i.e. that coarse grains were only slowly being discovered as a viable alternative to wheat or sheep production. Accordingly, it was decided to try a time trend as a shift variable in the supply function.

Various formulations were applied to represent the effects of price on supply. The B.A.E. index of prices received for grains other than wheat was used to represent the price of coarse grains. Some of the formulations that were tried were the lagged deflated value of the coarse grains price index, the lagged value of the ratio of coarse grains price to wheat price, the lagged value of the ratio of coarse grains price to wool price and Nerlovian expectations formulations applied to these two ratios. The ratios were used to test the importance of competition for resources between the various enterprises.

There was no case in which the coefficient on the coarse grains/wool price ratio, in all of its various formulations, was significant at five per cent. The coefficient on the time trend was significant at one, per cent in every case. In the equation using the lagged, deflated price index for coarse grains on its own, the coefficient on price was unexpectedly negative and not significant at five per cent. The coefficient on the lagged ratio of the coarse grains/wheat price was significant at five per cent and had the anticipated positive sign. Unfortunately the regression equation in which this ratio appeared yielded a sufficiently low Durbin-Watson statistic to indicate the presence of positive autocorrelation. However, when the t.d.l. formulation from Chapter 2 above was applied to this ratio, the regression equations in which it appeared all yielded positive coefficients on price that were significant at five per cent and in every case the Durbin-Watson statistic indicated zero autocorrelation. This was so regardless of the values of ω or n that were used in the t.d.l. formulation. Statistically there was no way of choosing between different values of ω and n since R^2, significance tests of coefficients,and Durbin-Watson statistic were much the same in each case. Regression results for the case of $\omega = 0.3$ and $n = 3$ years are as follows:

$$CGA_t = 174.5 + \underset{(5.8)}{15.1^{*}} E\ (Pog/Pwt) + \underset{(15.4)}{224^{**}}\ TIME$$

$$R^2 = 0.91$$

$$D\text{-}W = 1.61$$

* Denotes significance at five per cent

** Denotes significance at one per cent.

where:

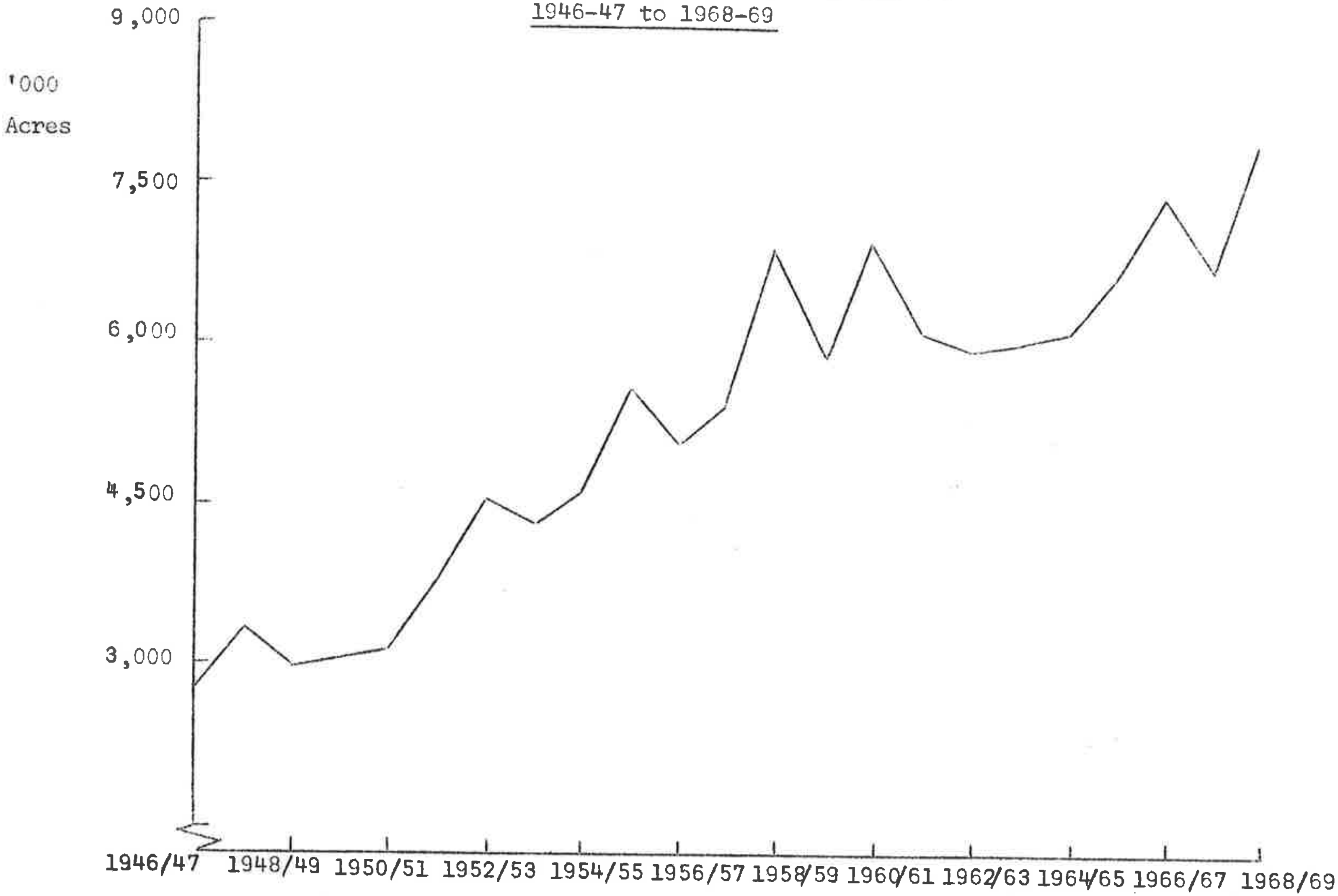
CGA_t	=	coarse grains acreage in year t, in thousands.
$E(Pog/Pwt)$	=	Nerlovian expectations formulation applied to the ratio of coarse grain prices to wheat prices for $\omega = 0.3$ and $n = 3$ years.
TIME	=	time with base 1945-46 = 0.

Calculations of the price elasticity of supply were made at average levels of all variables for different values of ω and n. The range of the estimates was 0.22 to 0.35 which compares favourably with Powell and Gruen's three sector model estimate of 0.28. There was a tendency for the estimates to be at either end of the range and none was clearly in perfect accord with Powell and Gruen's result. Hence it is felt that for predictive purposes any of the expectations formulations is suitable. For simplicity, preference might be given to the case presented above in which $\omega = 0.3$ and $n = 3$.

FIGURE 5

TOTAL COARSE GRAIN ACREAGE AUSTRALIA -

1946-47 to 1968-69



Source: C.B.C.S., Rural Industries Bulletin, various issues.

CHAPTER 4

SUPPLY FUNCTIONS FOR FRUIT, VEGETABLES, SUGAR AND HAY.

FRUIT AND VEGETABLES

Introduction

In 1968-69, the gross value of production of all fruit and vegetables, including vineyards, accounted for 20 per cent of the gross value of all crop production and almost 9 per cent of the gross value of all rural production. Hence these industries are quite important in determining total farm income. However, because of the widely varying conditions under which fruit and vegetables are produced in Australia, the concept of an aggregate fruit and vegetables supply equation is clearly ludicrous. The very minimum degree of disaggregation that is warranted is to divide the sector into two and have a supply function for fruit separately from a supply function for vegetables, since they are in fact very distinct and separate industries The supply response to a price change is likely to take around five years for the fruit industry while it may occur within the space of one year for the vegetable industry. Furthermore, there is very little competition between the two enterprises for resources with growers being specialised in one or the other.

From the point of view of supply analysis there are rewards to even further subdivision. For example, the fruit sector could perhaps justifiably be separated into citrus fruit, vine fruit and other. There would be some overlapping and substitution in production between these areas but there is probably sufficient specialisation in each to allow better estimates of supply responses to be made from a disaggregated than from an aggregated model. In the vegetable industry, it has already been shown[1] that useful information can be obtained from looking at the potato industry in different producing areas as if they were essentially different industries.

Two considerations operate against a disaggregated treatment in this study. First, sufficient data are not readily available on a disaggregated basis. Second, if disaggregation were allowed here, the total number of supply equations to be estimated for the rural sector would become quite large. While modern computers facilitate estimation and prediction from large numbers of equations, it is still felt that many equations would make the model cumbersome and difficult to use. Thus it was decided to concentrate on formulating two separate supply functions, one for fruit (including vine fruit) and one for vegetables.

Fruit

Fruit growing is a fairly specialised activity in Australia and there appears to be little scope for growers to shift resources between fruit growing and other enterprises. The 1965-66 Classification of Rural Holdings showed that of 454,460 acres devoted to fruit

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1. See Mules, T.J. and Jarrett, F.G., <u>op.cit.</u>, pp.52-59.

production in that year, 84 per cent of it was on properties whose principal activity was fruit growing.[2] There were 16,692 such properties and the percentage of them involved in other enterprises was as follows:

Activity	Per Cent
Wheat	0.9
Sheep	9.0
Beef Cattle	17.3
Dairy Cattle	6.7
Pigs	5.3

It should be noted that there is no single enterprise which is carried on in significant proportion with fruit growing. The above percentages are to be contrasted with the well known wheat-sheep mixture in Australian agriculture where in 1965-66 of 54,936 properties involved in wheat growing, some 62 per cent of them were also carrying sheep. On the basis of the high degree of specialisation of the fruit industry, it was decided that prices of other products would not be relevant in determining fruit supply. The B.A.E. index of prices received for all fruit (including vine fruit) was used as the only price variable in the supply model. This index was deflated by the index of prices paid by farmers and three separate specifications were made using the deflated index:

(a) the value of the deflated index in the year t-5. This is to take account of the fact that it takes approximately five years for a production decision to "bear fruit".

2. Commonwealth Bureau of Census and Statistics, Classification of Rural Holdings by Size and Type of Activity, Bulletin No. 7 - Australia, 1965-66, Canberra, 1968, pp.12-14.

(b) the t.d.l. formulation discussed in Chapter 2 above. The formula was applied for values of n of 3 and 5 years. The 5 year formulation gave superior results in every regression tried, thereby giving some justification to the assumption of a five year lag in supply response.

(c) an Almon distributed lag formulation. This was applied for two separate assumptions; one assuming progressively increasing importance of the deflated index up to the year t-5, the other assuming symmetrically declining weights for two years to either side of t-3. Again, superior regression results for equations in which the greatest weight was given to the deflated index in t-5 bore out the assumption of a five year lag.

For many agricultural industries, heavy reliance on export markets means that even current prices can be taken as pre-determined in so far as the Australian rural sector is concerned. However, this is not the case for many fruit commodities where the quantity coming onto the market each year does significantly affect the price. Thus, if current prices were included in the above specifications they would have to be treated as endogenous to the system. Since none of the three specifications includes the current value of the price index, they can all be properly treated as exogenous. This does nothing to help explain what determines prices and any forecasts from the model must be conditional upon some assumption about prices.

Two different variables were considered as possible candidates to represent the effects of technical change on supply. Fertiliser usage was one and is defined exactly as for fertiliser usage on the wheat crop. Since data on the number of acres under fruit which are irrigated each year are available, it was considered that the percentage of total area under fruit which was irrigated should also be a candidate for a surrogate to represent technical change. Both variables have shown a steady upward trend over the period and both are likely to have been yield increasing. No meaningful single series on yield can be arrived at for the fruit industry but an examination of yields on a commodity by commodity basis shows that most commodities have experience rather unsteady upward trends, the unsteadiness due possibly to such things as the incidence of frosts and diseases.

In addition to an effect on yields, increasing use of irrigation is likely to shift the minimum point of the average cost curve outwards due to increasing economies of large scale operation. This would result in more output being produced at a given price, i.e. more acres being planted to fruit trees and vines. Ideally, if we knew the marginal products of fertiliser use and water use and if we had details of the quantity of irrigated water used, then a combined index of the two variables could be constructed in terms of their output equivalents. Even if information on marginal products for each commodity were available from agricultural scientists, the data on irrigated water usage on a commodity basis are certainly not available. Hence, one or the other must be chosen, since their high degree of inter-correlation (correlation coefficient of 0.93) prevents them both from being used. Although the coefficients on both variables were always highly significant, regressions in which the irrigation percentage was used gave consistently better explanation in terms of R^2 and so this variable was chosen to represent technology.

Unfortunately, none of the price formulations referred to above performed well in regressions in which total acres under fruit was used as a dependent variable. In every case the coefficient on the price variable had an unexpected negative sign, sometimes significant at five per cent, sometimes not significant. In view of the fact that both the simple and partial correlation coefficients between each formulated price variable and the dependent variable were inexplicably negative, it was decided to experiment with different specifications to see if results could be obtained that seemed more reasonable.

The first variation which was tried postulated a kind of "money illusion." Instead of deflating the fruit price index by the index of prices paid, it was assumed that growers respond to the current values of prices received and do not take into consideration the changing "real" value of prices. The assumption involved here is difficult to either support or refute. The publicity given to the effects of the post-war cost-price squeeze on agriculture, both in academic journals and in the rural press, could be expected to make farmers generally aware of the "real" value of prices they receive for their products. However, the average fruit growing property is fairly small (22.8 acres in the C.B.C.S. 1965-66 Classification of Rural Holdings) and fairly specialised. To the extent that this makes the average fruit grower insular in outlook and less economically aware than his "big-business" colleagues in other rural sectors, the hypothesis of a money illusion is more easily substantiated.

In the regressions in which the "money" price formulations were tried with acres as dependent variable, they did not perform much better than the "real" price formulations. The partial correlation coefficients between acres and price and the regression coefficients remained negative although the simple correlation coefficients were now positive and quite reasonable at around 0.5. The coefficient on the irrigated percentage variable was positive and significant at one per cent in every case.

The Durbin-Watson statistic indicated positive auto-correlation to be present in every case and even after removal of this using the Hildreth-Lu procedure, the regression coefficients on price remained negative. It is felt that the reason for the negative regression coefficient on price in these cases is due to intercorrelation between the price formulation and the irrigated percentage. The simple correlation coefficients between these was around 0.8 which is quite high. Thus it is likely that the effect of price is being absorbed into the coefficient on technology (irrigated percentage).

In an attempt to step around this problem, a further variation of the specification was tried. Instead of acres under fruit, it was decided to try quantity of production as the dependent variable. This presented something of a problem since "production" in this industry is composed of a conglomerate of apples, bananas, apricots, grapes, etc.

which are not additive in quantity terms. The problem was solved by valuing each year's production of each commodity at constant prices and then adding the values together. The "prices" that were used for this purpose were C.B.C.S. average unit gross values of rural production The unit gross values (U.G.V.'s) were averaged over the three years 1960-61 to 1962-63, which is the base period for all B.A.E. price indices.

Regressions were run using this "quantum" of production as dependent variable with both "real" and "money" price formulations as explanators. In all the regressions in which "real" price formulations appeared, the simple and partial correlation coefficients (and hence the regression coefficients) between price and quantum of production were negative. However, when the "money illusion" assumption was made and "money" price formulations were used, they had high positive simple correlation coefficients with quantum of production (around 0.6 to 0.8) and positive regression coefficients. The regression coefficients on price were not significant at five per cent in any of the regressions. This lack of significance is attributable to either or both multicollinearity or autocorrelation. The Durbin-Watson statistic indicated positive autocorrelation to be present in every case while the inter-correlation coefficients were fairly high at around 0.8.

The Hildreth-Lu procedure was applied to the data to remove autocorrelation. The sum of squared residuals achieved a minimum in the acceptable range for ρ for each price formulation. Unfortunately, the coefficient on price still did not achieve significance at five per cent in any case. Since the intercorrelation coefficients for the transformed data were still fairly high at around 0.7, this lack of significance can be attributable to multicollinearity. Accordingly, the coefficients can be considered to be unbiassed but inefficient and thus can be used for forecasting providing the inefficiency is recognised.

Price formulations (a) and (c) above gave results with the highest R^2 when the Hildreth-Lu procedure was applied, the R^2 being calculated from the observed and predicted values of the original data, not the transformed data. The coefficient on price using formulation (a) gave a slightly higher R^2 and had a slightly superior Students' t value than that using formulation (c). The regression equation using formulation (a) after application of the Hildreth-Lu procedure is as follows:

$$FQP_t = -59 + \underset{(0.8)}{4.6^{**}} FIP_{t-1} + \underset{(0.2)}{0.2}\, PF_{t-5}$$

$$R^2 = 0.90$$

$$D\text{-}W = 1.92$$

FQP_t = Quantum of fruit production in year t, thousands of dollars,

FIP_{t-1} = Percentage of total area under fruit which is irrigated in year t-1,

PF_{t-5} = undeflated B.A.E. index of prices received by farmers for all fruit in year t-5.

The coefficient on FIP_{t-1} was significant at one per cent. Statistically, the results presented for this equation have most of the desirable properties, even the inefficiency of the price coefficient can be tolerated for forecasting purposes. Economically, the assumptions underlying the equation may cause some raised eyebrows. For example, how can Queensland banana growers and Tasmanian apple growers be thrown together into the same supply equation? The fact is that they should not be and that Australia has a dire need for empirical workers to get into this field, disaggregate it and come up with a good sound model of the Australian fruit economy. Until this is done, however, this study presents at least a usable aggregate equation so that an overall model explaining farm income may be arrived at. Accordingly it is felt that the equation presented above is the best that can be obtained for the fruit industry given the present aims and resources.

Vegetables

In terms of gross value of production, the commercial vegetable industry in Australia was about two thirds the size of the fruit industry in 1968-69. Unlike the fruit industry, some work on supply on a disaggregated basis has already been done for the vegetable industry, mainly on potatoes.[3] While these studies are useful in determining what factors influence acres planted to potatoes, they do not provide much insight into what determines the division of land

3. See Mules, T.J. and Jarrett, F.G., op.cit. and also Longworth, John W. and O'Loughlin, Edmond J. "Supply Responses for Potatoes in Five New South Wales Shires", Review of Marketing and Agricultural Economics, Vol.36, No.2, Sept.1968, pp.125-138.

between potatoes and other vegetables. A B.A.E. survey of the Australian potato industry for the years 1961-62 to 1963-64 showed that only in one region, the Victorian "Central Highlands" area, did potato production contribute more than 50 per cent of gross farm returns on the average potato farm.[4] In every State, other vegetables accounted for a significant proportion of gross farm returns, ranging from 10.4 per cent in New South Wales to 37.8 per cent in Queensland.

It seems reasonable to suppose that the division of land resources between potatoes and other vegetables would depend upon relative prices <u>within</u> the vegetable group while the division of resources between vegetables and other enterprises would depend upon the relative returns <u>between</u> vegetables and those other activities. The B.A.E. survey indicated that dairying was an important complementary activity in Western Australia, Tasmania, one region in Victoria and one region in New South Wales, while wool production was important in another New South Wales region. The ideal situation would be to take a region by region approach to supply, taking into account returns to the relevant competing activities in each region. While this would be useful from the point of view of the potato industry, it would not shed much light on what factors influence the supply of other vegetables outside the potato industry.

It is difficult to ascertain what proportion of other vegetable production is grown outside the potato industry. Potatoes themselves account for about one third of the gross value of all production of

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4. Bureau of Agricultural Economics, <u>The Australian Potato Industry - An Economic Survey, 1961-62 to 1963-64</u>, Canberra, October, 1967, pp. 76-78.

vegetables. If it is assumed that all of this potato production is on potato farms and that the value of other vegetables produced on these farms is about half of the value of their potato production, then the potato industry would still only account for about a half of the value of all vegetables produced. No information is available on the conditions under which the other half is produced. It seems reasonable to suppose that the "market-garden" type of vegetable producers would account for most of it. The Australian Standard Industrial Classification lists vegetable production as a separate industry[5] indicating that it is not carried on predominantly with any other activity. These pieces of information indicate that vegetable production should be treated as one industry for supply analysis and that there is no major activity competing for resources with vegetable production in total.

Accordingly, the first approach to vegetable supply for this study was to attempt to explain annual acreage under vegetables. Since there appeared to be no single enterprise in a significant mix with vegetable production, the B.A.E. price index for vegetables was the only price variable used as an explanator. In separate specifications, both the "real" (deflated) and "money" values of the index, lagged one year,were used. Also tried were Almon distributed lag and t.d.l.

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5. C.B.C.S., Australian Standard Industrial Classification, Volume 1 - The Classification, Canberra, 1969, p.75.

formulations similar to those used above for the fruit industry.[6] To represent the effects of technology, both the fertiliser usage per acre and the percentage of the crop that was irrigated were tried. This is also similar to the treatment for the fruit industry.

In these initial regressions very poor R^2's were obtained. The coefficients on the different price variables were generally positive for "real" prices and negative for "money" prices. The coefficient on the technology variable was always negative regardless of which variable was used to represent technology. Over the period being studied, acres under vegetables have shown a slight and unsteady downward trend while the quantum of production[7] has shown a steady upward trend, as have the two technology variables. It seems likely that technology may be increasing productivity at a faster rate than that at which population is causing demand to grow. It is thus having the effect of slightly reducing the acreage over time and results in a

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6. In view of the short production period and low barriers to entry, it might be expected that where annual data are being used, the current value of price (i.e. in year t) would affect vegetable supply. If this is admitted, a demand function for vegetables must also be specified since the problem of contemporaneous variables arises. This was attempted using both acreage and production as dependent variables in separate models and using both two stage least squares and indirect least squares estimation methods. All results were unsatisfactory, giving mostly negative and insignificant coefficients on current price in the supply function and an unexpected negative coefficient on population which was specified in the demand function. Accordingly, it was felt that for most crops, the relevant price that was being considered for production decisions was at least a year in the past.

7. Quantum of vegetable production was calculated similarly to quantum of fruit production, by valuing the volume of production of each commodity at average 1960-61 to 1962-63 unit gross values.

negative correlation between acres and technology.[8]

Because of the poor fit of these initial regressions and because of the dubious nature of the relationship between acreage and technology, the regressions were re-run using quantum of vegetable production as dependent variable. The degree of explanation (R^2) was much improved being a tolerable 0.7 to 0.73. For the equations in which "real" prices were used, the coefficient on price was positive in every case but never achieved significance at five per cent. For the two types of distributed lag formulations, the highest R^2's were obtained for the shortest period of lag. This is to be expected with vegetable production which has a short production period and low barriers to entry.

In the equations using "money" prices, the price coefficient had the anticipated positive sign only in the models which employed fertiliser usage as a technology surrogate. Again the shortest period lags gave superior performance but the price coefficient did not achieve significance at five per cent in any equation. In every equation, both for "real" and "money" prices, the technology surrogates had the expected positive sign and the coefficients were always significant at one per cent. As for the fruit model, the two technology variables could not both be used in the one equation because of the high degree of inter-correlation between them. In every equation, both for "real" and "money"

8. The economics of this argument are somewhat weak. They can be strengthened as follows. Population is causing demand for vegetables at a given price to grow at a certain rate. This rate is less than the rate at which total supply from a given acreage is being increased by technology. Thus growers, if they plant the same acreage must accept a lower price; if they want the same price they must plant fewer acres. In practice the response is likely to be a mixture of the two, some reduction in price being acceptable because of the reduction in costs attributable to technology and some shift out of vegetables into other enterprises, thus reducing acreage under vegetables.

prices, the Durbin-Watson statistic indicates positive autocorrelation to be present. The Hildreth-Lu procedure was applied to all models using "real" prices and to those models using "money" prices that had fertiliser usage as a technology surrogate.

In all cases in which the procedure was applied, the sum of squared residuals reached a minimum close to the estimated value of ρ. For the equations using "real" prices, slightly higher R^2's were obtained when the irrigation percentage was used rather than fertiliser usage as the technology variable. For both "real" and "money" prices, the formulations on price which gave the most significant price coefficients were the simple one year lag and the t.d.l. for $\omega = .3$ and $n = 3$. A brief summary of these results is given in the table below.

TABLE 3

Summary of Regressions to Explain Quantity of Vegetable Production

Explanators	Students t value		R^2	Durbin-Watson Statistic
	Price Coeff.	Tech. Coeff.		
VPR_{t-1}, VIP_{t-1}	1.23	6.08**	0.72	2.29
$E(VPR)$, VIP_{t-1}	1.16	6.08**	0.73	2.30
VPM_{t-1}, VFU_{t-1}	2.11*	3.35**	0.69	2.07
$E(VPM)$, VFU_{t-1}	2.35*	2.44*	0.68	2.18

* Denotes five per cent significance

** Denotes one per cent significance

VPR_{t-1} = the deflated B.A.E. index of prices received for all vegetables, lagged one period.

$E(VPR)$ = the index of expected value of VPR using the Nerlovian distributed lag formula with $\omega = 0.3$ and $n = 3$ years.

VIP_{t-1} = the percentage of total area under vegetables which was irrigated in year t-1.

CPM_{t-1} = the undeflated or "money" index of prices received for vegetables in t-1.

E(VPM) = the Nerlovian index of expected value of VPM, again with $\omega = 0.3$ and $n = 3$ years.

VFU_{t-1} = the fertiliser usage per acre on the vegetable crop for the year t-1.

As can be seen from Table 3, the models in which "money" prices were used had much higher Students t values for the price coefficient than the models using "real" prices. The D-W statistic for all models is now in the non-rejection region for the hypothesis of zero autocorrelation. On balance, it is felt that the models using "money" prices are to be preferred, the fit being much the same but the coefficients being statistically more significant. In particular, in view of its simplicity of formulation and overall statistical significance, the model using the one year lag was chosen to represent vegetable supply. The final regression equation, in terms of original variables was thus:

$$VQP_t = -30.9 + \underset{(0.06)}{0.13^{*}} VPM_{t-1} + \underset{(0.04)}{0.13^{**}} VFU_{t-1}$$

$$R^2 = 0.69$$

$$D\text{-}W = 2.07$$

where VQP_t = quantum of vegetable production in year t in thousands of dollars.

SUGAR

Introduction

Quotas, growers' licences and import prohibition ensure strict Government control over Australian sugar production. Queensland and New South Wales are the sole producing states with the former accounting for 95 per cent of the total. The mechanisms of licensing, quota restrictions and marketing are described elsewhere[9] but they add up to an industry where annual production is almost totally controlled by arbitrary decisions made according to "needs". Domestic consumption needs are likely to vary with domestic population. However, from 1953-54, over half of Australia's annual production has been exported and this proportion has risen to almost 75 per cent in 1968-69. Thus it seems likely that in allocating licences and production quotas, the authorities (Queensland Sugar Board) are likely to have been placing progressively heavier weight on export demand. Since Australia's exports are known in advance with a fair degree of certainty, due to the various sugar agreements that have been or are in existence, the authorities can determine production quotas with almost perfect knowledge of demand.

Under these conditions, and assuming the industry is likely to remain under strict Government control, there is little to be gained from a policy viewpoint in estimating a supply equation. With

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9. See Bureau of Agricultural Economics, Rural Industry in Australia, Canberra, 1966, pp.55-56 and 78-79. Also any recent copy of the Commonwealth of Australia Year Book contains details of the production and marketing controls.

production under such tight reign, policy makers are not faced with any problems of predicting farmers responses and thus have no need of a behavioural equation to explain supply. The only remaining source of production instability is weather, and there seems to be sufficient flexibility to absorb this in Australia's export committments to the various overseas sugar agreements.

However, for the purpose of developing a set of equations to explain farm income it is desirable to separate and quantify the factors which affect the gross value of sugar production. This is to enable predictions to be made about farm income. Thus it is necessary to develop a model which explains sugar production and which incorporates the effects of Government control of the industry.

The Model and the Results

Since production is tightly controlled and variability due to weather is relatively slight,[10] a good case could be made for using actual production as the dependent variable in a supply equation. However, the series of acres of cane cut for crushing was used as the dependent variable, partly because it makes the treatment of the sugar industry more or less consistent with the treatment of other crops and

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10. The coefficient of variation of sugar yields over the period 1946-47 to 1968-69 was relatively high at 16%. For wheat yields it was 19%. However, for sugar this variation reflects a fairly steady upward trend rather than great instability. The average of the year to year percentage change in yield over the period was 11 per cent for sugar compared with 27 per cent for wheat.

also because it is felt that this series would be a direct reflection of the licensing and quota controls imposed on the industry.

In view of these controls, there seems little relevance in specifying a price variable in the model. Although the correlation coefficient between acres cut for crushing and the B.A.E. index of prices received for sugar, lagged one year, was positive and reasonably high at 0.66, this cannot be taken as evidence of a significant grower response to price. It seems, in fact, quite incongruous to even conceive of a price response given the institutional circumstances of the industry. The positive correlation mentioned is most likely a reflection of the time trend in both series. The trend in price is possibly brought about by the authorities' attempts to keep the sugar price increasing in line with the general rate of inflation or perhaps just as part of the inflation itself. The trend in acres is being brought about by the trend in domestic and export needs. Accordingly, it was decided to omit price from the model.

The most obvious variable which one could select to reflect domestic needs is the domestic population. Over the period being considered, the domestic consumption per head of sugar was reasonably constant. Apart from the two exceptionally high years of consumption, 1947-48 and 1950-51, consumption per head varied between 107 lb. and 118 lb. There is evidence of a very slight downward trend over time but the figure is sufficiently stable to permit the planning authorities to forecast reasonably accurately the year to year domestic requirements.

In view of the necessary lag which is likely to operate between a population rise and a rise in acres cut for crushing, the mean Australian population, lagged one year, was used to represent the effects of domestic needs on the dependent variable.

The next step is to specify a variable which represents the export needs. If Australian exports of sugar went wholly or pre-cominantly to a small number of countries and if Australia was the sole source of supply for these countries, then their combined populations could be used to represent their needs, assuming they had reasonably stable consumption patterns. However, this is not the case. At varying times over the period Australia's major customer has been either the U.K. or Japan with Canada and the U.S.A. as other important outlets. Australia has not been the sole source or even the major source of supply in these cases and thus the populations of these countries could not be used to reflect their export needs from Australia.

Accordingly, it was decided that the best variable that could be used as a first approximation to the current period's export needs would be last period's actual exports. In view of the relative year to year stability of Australia's exports due to the various export agreements and the fact that exports have shown a reasonably steady upward trend over time, exports lagged one year should be a fairly accurate reflection of export demands for the current year. It is recognised that a better solution to this problem would be to have a model which first predicts export needs. However, as this would seem to amount to a model of the world sugar market it was decided that this was outside the scope of this study.

The coefficients on both the domestic and export needs variables would be expected to be positive since an increase in needs should result in increasing quotas and hence more area planted and cut for crushing. It is not so clear what sign should be expected on a technology variable in the sugar supply equation. The series of fertiliser usage per acre fertilised showed a persistent upward trend over the period and thus recommends itself for use as a technology variable. Much of the technological innovation in the industry, however, has been on the side of mechanised harvesting and handling. As such, it tends to be cost reducing rather than yield increasing. The argument in favour of fertiliser usage, which was used above in the wheat section, as a technology variable, depends upon the technology increasing yields on marginal land, thereby making it profitable for previously uneconomic land to be brought into production.

This does not appear likely to be the case in the sugar industry, since the production controls would prevent such a response from occurring. Both the yield of cane per acre and the yield of sugar per acre crushed have shown fairly steady upward trends over the period. This would seem to be a result of the increased fertiliser usage. The effect of these increased yields would be to enable growers to fulfill their delivery quotas with fewer acres. Thus if quotas remained constant, a negative correlation could be expected between fertiliser use and acres cut for crushing. However, domestic and export needs and therefore quotas have been steadily expanding and acres cut for crushing have also shown a steady expansion. This would indicate that the rate of growth of "needs" has exceeded the rate of growth of yields. Thus both fertiliser usage and acres cut for crushing have steady upward time trends resulting in a simple correlation coefficient between them of 0.9. However, in view of the nature of the industry, it is felt that this cannot be taken as indicative of a behavioural relationship.

Accordingly, the apparent determinants of acres cut for crushing are domestic and export needs. Preliminary regressions using both as explanators revealed a high degree of inter-correlation between the variables suggested above to represent them. The inter-correlation coefficient was 0.95 and the coefficient on the Australian mean fiscal population for year t-1 appeared to be robbed of significance because of this. Thus a separate regression was run using only exports of sugar in t-1 as an explanatory variable. The results were as follows:

$$SAC_t = 210.2 + \underset{(0.01)}{0.22^{**}} SX_{t-1}$$

$$R^2 = 0.91$$

$$D\text{-}W = 1.81$$

where SAC_t = acres of sugar cane cut for crushing, year t, in thousands of acres.

SX_{t-1} = exports of sugar in year t-1, in thousands of tons.

The coefficient on SX_{t-1} was significant at one per cent, the R^2 is reasonably high and the D-W statistic is sufficiently high to enable the non-rejection of the hypothesis of zero autocorrelation using the Theil-Nagar test. It seems clear that the above equation would make a very useful forecasting equation for the purposes of forecasting the sugar industry's effect on total farm income. In using it for such a purpose, the industry should be kept under close watch to ensure that certain provisos are met. The degree of control of the industry must be maintained and the strong correlation between exports and domestic needs should continue. Also,orderly export marketing via international agreements is necessary in order to allow a straight link from last year's exports to this year's production. Should any of these conditions cease to be fulfilled, the industry will have more flexibility and in making its production decisions and the simple equation presented above will no longer suffice as an abstraction of its behavioural characteristics.

HAY

The Commonwealth Statistician values all hay produced on farms in his gross value of production figures, even hay produced for own use. The unique position of hay is brought about by the fact that it can be a cost to the farmer as well as a revenue earner. The Statistician only values that quantity of hay which is actually used in a year in his cost figures.[11] The aim of this section is to explain that quantity of hay which is produced each year. Many farmers produce their own hay and hay that is sold commercially is quite often put on the market because

11. The cost of hay used is accounted for below in a cost equation to explain total seed and fodder costs.

a farmer has an excess over and above his needs. Most farmers do not regard production of hay as a commercial, income earning enterprise, and it is therefore unlikely to be very price responsive. The B.A.E. index of prices received for hay is in fact extremely unstable. This instability is most likely due to supply being price inelastic while demand for hay for feeding livestock is subject to large shifts due to weather.

Since hay is produced for feeding livestock, a major influence on acres under hay[12] would be livestock numbers. An index of livestock numbers was calculated by using average 1960-61 to 1962-63 saleyard prices of sheep, cattle and pigs to value livestock numbers and from the total value of livestock so calculated an index was constructed. It is recognized that saleyard prices may not be an effective guide to the absolute value of livestock numbers but their function here is as weights and it is felt that as such they would reflect the relative importance of sheep, cattle and pigs in total livestock numbers.

Weather can affect hay production in a number of ways. Most simply, in a good season production is likely to increase, other things assumed equal. However, in bad seasons hay is used to protect the value of the farmer's income earning assets i.e. his livestock. Expectations of a bad season may therefore provoke increased hay production. The actual occurrence of a bad season will tend to reduce

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12. Acreage is again regarded as the decision variable in this section, hay yield per acre being sensitive to weather variations. Actual production of hay was highly negatively correlated with the current value of the drought mortality index.

actual production. The decision variable, acres under hay, is most likely going to respond to farmers' weather expectations. The drought mortality index (DMI), lagged one year, was tried as a proxy for farmers' weather expectations in the current year. Also, various forms of the Almon distributed lag were applied to DMI in an attempt to obtain an index of weather expectations that allowed farmers longer memories than just one year.

A further feature of hay production which is unique is the fact that at any one time farmers will have significant stocks of hay on hand. The larger their stocks on hand the less they will be inclined to produce. Fortunately, the Statistician collects and publishes data on stocks of hay on hand and in the regressions presented below the stock of hay at the beginning of the year was used as an explanatory variable.

In testing for price responsiveness of hay acreage, both the deflated and undeflated B.A.E. index of prices received for hay were used. They were tried in simple one year lag form and in t.d.l. form. In most of these cases the coefficient on price was unexpectedly negative and in the few cases where it was positive, it lacked statistical significance. There is a possibility that this lack of significance is attributable to multicollinearity since in many cases the simple correlation coefficient between the price variable and the stocks of hay variable was around -0.7.

It is also possible that the negative price relationships are due to specification error. In particular, in none of the models tested was any account taken of technology. If the demand for hay is less than infinitely elastic with respect to price, then,as technological advances shift the supply curve outwards over time, a negative simple correlation will be observed between price-quantity couplets which reflects the slope of the demand curve rather than the supply curve, all other things unchanged. No simple measure of advances in technology in hay production is readily available from the data. Factors such as irrigation and fertiliser would obviously be relevant, however data for both of these items are not separately available for hay production. In an attempt to account for technology, all the regressions were re-run with a time trend included. Unfortunately, the coefficients on price remained negative and to make matters worse, it was discovered that there is a strong correlation between time and the livestock index (0.97) and between time and stocks of hay (0.81) and this multicollinearity reduced to insignificance all but one of these coefficients.

The poor over-all performance of the price variable led to the decision to discard it from the model entirely. This action can be defended on the grounds that hay production is not regarded as an income earning enterprise in itself by most farmers, its primary purpose being to provide feed for livestock. If it is responsive to any price series, it might be expected to respond to livestock prices, however, this effect is accounted for by the livestock numbers index.

The problem of specifying the effects of technology is one that remains and it is bound up with the problem of multicollinearity. Any technology surrogate is most likely going to be characterised by a time trend as are both the livestock numbers index and stocks of hay. It was therefore decided to ignore technology, with the usual caveat concerning the continuance of multicollinearity.

In all models in which the simple lagged value of DMI was used as an index of drought expectations, its coefficient had the expected positive sign but was not statistically significant. The Almon distributed lag formulation applied to DMI was considerably more successful as an index of drought expectations. The formulation which resulted in best explanation (highest R^2) and greatest statistical significance was the one which peaked in t-1 and tailed smoothly off to zero in t-6.

The regression results for this model are as follows:

$$AH_t = -7{,}237 + \underset{(9.1)}{95.2^{**}} LVSK_t + \underset{(0.8)}{4.2^{**}} ALDIS - \underset{(0.07)}{0.28^{**}} HSTK_t$$

$$R^2 = 0.87$$

$$D\text{-}W = 1.73$$

where AH_t = acres under hay in year t,

$LVSK_t$ = index of livestock numbers at the beginning of year t, base average 1960-61 to 1962-63 = 100,

$HSTK_t$ = stocks of hay on hand at the beginning of year t,

ALDIS = variable obtained by applying an Almon distributed lag to DMI with a lag of five years and a peak in t-1.

The weights implied by the coefficient on ALDIS were as follows:

$$w_1 = 5.0, \quad w_2 = 4.8, \quad w_3 = 4.2, \quad w_4 = 3.2, \quad w_5 = 1.8$$

All coefficients in the above equation are highly significant and of the expected sign. The positive sign on ALDIS is anticipated since if expectations of a drought are high, more acres would be put under hay to provide more feed for livestock during the expected drought.[13] The R^2 is high and the D-W statistic allows non-rejection of the hypothesis of zero autocorrelation using the Theil-Nagar test.

In conclusion it can be said that the above equation provides a useful tool for understanding the factors involved in hay production. Forecasts of hay production may be simply obtained by an identity combining forecasted acreage and yield per acre, which is taken as weather determined.

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13. The positive coefficient on ALDIS may also be attributable to drought recovery. Very substantial increases in hay acreage occurred in both 1958-59 and 1966-67, years which followed severe droughts and high values of the drought mortality index.

CHAPTER 5

SOME GENERAL CONSIDERATIONS REGARDING THE LIVESTOCK INDUSTRIES

The livestock industries seem to fall naturally into five main categories, viz. wool, sheepmeat, beef, dairying and pig raising. Despite the fact that on individual farms wool-sheepmeat and beef-dairying may be inseparable enterprise mixes, there is a reasonable amount of data available separately on these industries. For each of these industries, it was considered that the number of animals on hand at the beginning of the year would best represent the farmer's decision variable. However, actual production of livestock products during a year depends not only on the size of the animal population but also on its reproduction capacity or fertility.[1]

It is possible to combine size and fertility into one single measure of production potential. This was done by Hildreth and Jarrett in their study of the U.S. livestock-cereals complex,[2] not only for size and fertility, but also for weight-gain potential for meat production. Sufficient data are not available for weight-gain potential to be included for Australia and so only size and fertility were accounted

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1. This was forcefully shown for the sheep population in Watson, A.S., An Economic and Statistical Analysis of Factors Affecting the Rate of Growth of the Australian Sheep Population, unpublished Ph.D. thesis University of Adelaide, 1970.

2. See Hildreth, Clifford and Jarrett, F.G., A Statistical Study of Livestock Production and Marketing, Cowles Commission Monograph No.15, John Wiley & Sons, Inc., New York, 1955, pp.35-39.

for. Details of how this was done are contained below in the relevant sections. For the beef and dairying industries it was not possible to do this at all because of a change in 1964 in the definitions of beef cattle and dairy cattle on statistical returns made by farmers to the Commonwealth Statistician. Thus consistent time series data are not a available on numbers of beef cattle and dairy cattle and a way around this problem had to be found for these industries.

From a purely statistical point of view it is not necessary to develop equations to explain the size-fertility of animal populations at the beginning of the year, since with respect to the current year's production of livestock products, the size-fertility can be regarded as pre-determined. However, it was felt that this would be avoiding the issue of what factors affect livestock production and so, where applicable, a model was developed to explain size-fertility. This may also have consequences for agricultural policy since it is size and to some extent fertility of the animal population which is the operating variable for farmers' production decisions.

The general approach adopted then, was to explain current production of livestock products using size-fertility of the population as an explanatory variable. Thus, biological constraints on supply adjustment are reflected in the coefficient on size-fertility rather than the price coefficient. For the beef industry, this general approach was modified in order to obtain an estimating equation which was free of the size-fertility variable. Details are given in Chapter 7. For dairying, a totally different approach was used. Also, apart from dairying, it was generally considered relevant to include the current period's price of the product in the supply equation. The prices used were deflated B.A.E. indices. For wool, this was not successful indicating that if they have the sheep, farmers will shear them regardless of current price. However, the reasonable success of current price in the meat models suggests that it is a good indicator of farmers' short-run price expectations in situations where they have to decide whether to sell or hold livestock.

The inclusion of current price in the meat supply equations has an important statistical consequence. Since Australia only exports at most half of her annual production of beefmeats and sheepmeats and virtually no pigmeats, current price cannot be taken as predetermined by world demand and thus must be influenced by domestic supply. Hence, current price should truly be regarded as endogenous and interdependent with current supply. To complete the system, a demand equation should be specified to explain the market clearing price. Thus the system be becomes a simultaneous one indicating the applicability of two stage least squares (2SLS).

Once a demand equation is introduced, then not only must the interdependency of production[3] and price be recognized but also the possibility of interdependence of demand for the different types of meat. Thus in a demand equation explaining the price of cattle, it may be considered necessary to include as explanators the prices of sheep and pigs. Other things equal, the higher the price of competing meats, the higher will be the price of beef, if the meats are substitutes. This suggests the need for an overall model of the meat

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3. The dependent variable in all supply equations was slaughterings.

economy with interdependence between the demand equations and between each supply equation and its related demand equation. Such a model was in fact tried, using 2SLS but many coefficients had the wrong signs and variances of the coefficients were so high that very few t values even exceeded unity.

The reasons for these poor results are not difficult to see. The model that is being postulated here is essentially one of the auction end of the meat market. The production variable is slaughterings and the price index refers to prices received by farmers. Thus the demand equations reflect demand at auctions which is mainly derived demand. Arbitrarily it would be expected that, once consumers' preferences for various meats at relative prices had been established at the retail level, these preferences would be transmitted through the system to the auction yards in the form of specific orders for so many prime heifers, so many lambs etc. In these circumstances, demand at auction would not be expected to be sensitive to relative prices.

Other studies of the Australian meat market have suggested that the auction system does in fact operate on this order system. Using quarterly data they have found virtually no evidence of demand substitution at the auction level with substitution tending to increase through wholesale to retail.[4] On the basis of the results of these studies and of the initial results from the overall 2SLS model it was decided not to allow for demand substitution between meats. Accordingly,

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4. See Marceau, Ian William, Factors Affecting the Demand and Price Structure in the New South Wales Meat Market, unpublished M.Ag.Sc. thesis, University of Sydney, 1965, pp.48-81 and also Papadopoulos, Chrysanthi, A Model of the Australian Meat Market, unpublished B.Ec. (Hons.) thesis, University of Adelaide, 1971,pp.66-126.

each simultaneous meat supply and demand model is a complete system and each may be considered separately.

Another general issue in relation to the demand equations is that of shift factors. Demand for foodstuffs such as meat is generally thought to be not very income elastic. B.A.E. household meat consumption surveys for Sydney and Melbourne have tended to confirm this with estimates of income elasticities between 0.2 and 0.3.[5] The time series studies of Taylor,[6] Marceau[7] and Papadopolous[8] also support the hypothesis that demand for meat is not very income elastic. Accordingly, it was felt that population size would be a better shift factor than income.[9] However, when it was tried in 2SLS models, it was found to be highly correlated with many other explanatory variables, most notably with slaughterings. Considerably greater efficiency was obtained when instead of population, personal disposable income per head, deflated by the Consumer Price Index, was used as a shift factor. Since the coefficient on income was in many cases quite significant it is clear that despite a fairly low elasticity, income is an important shift factor in the demand equations. The separate effect of population on price may never be quantifiable due to the likely continuance of the correlation between population and slaughterings.

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5. See B.A.E., Household Meat Consumption in Sydney, Beef Research Report No.3, Canberra 1967, pp.22-24 and B.A.E., Household Meat Consumption in Melbourne, Beef Research Report No.8, Canberra, 1970, pp.26-28.

6. Taylor, G.W., "Meat Consumption in Australia", Economic Record, Vol. 39, No.85, March 1963, p.85.

7. Marceau, Ian William, op.cit., pp.74-80.

8. Papadopolous, C., op.cit., pp.125-136.

9. The B.A.E. surveys found a negative per head elasticity with respect to household size but they suggest that this is due to economies of scale and reduction of waste.

CHAPTER 6

SUPPLY FUNCTIONS FOR WOOL AND SHEEP AND LAMBS FOR SLAUGHTER

WOOL

There has been a considerable amount of research done into factors affecting wool supply in Australia[1] and it would seem somewhat presumptuous to suggest that the present author can do better. However, with the exception of Watson, all the researchers have taken a straight price-supply relationship approach using various distributed lags and other formulations. None of them have attempted to incorporate Watson's "demographic" approach into a classical supply framework. Thus the price coefficients in their models are influenced by biological constraints on increasing sheep numbers.

The present author believes that there are gains, at least in understanding, and possibly also in forecasting, from attempting to include demographic factors into a supply function. Firstly, a variable TNF_t is defined to reflect both the size and the reproductive capacity of the sheep population at the beginning of year t. The reproductive capacity or fertility is allowed for by counting each breeding ewe in the population at the beginning of t as 1.7 rather than 1.0. This allows for the fact that the average lambing rate per ewe mated over the sample period was 0.7.[2] Thus by applying this rate to the total number

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1. In addition to the Powell and Gruen work there is Watson, A.S., op.cit.; Dahlberg, D.L., "Supply Responses for Wool in South Australia, 1949-61," Australian Journal of Agricultural Economics, Vol.8, No.1, June 1964, pp.57-65 and B.A.E., Supply Relationships in the Australian Sheep and Wool Industry, Wool Economic Research Report, No. 19, Canberra, Feb.1971.
2. This rate was fairly stable over the period, varying between 0.62 and 0.75.

of breeding ewes, an estimate of the ceiling of fertility is made, since not all breeding ewes are mated in a year.

Statistically it is possible to regard TNF_t as pre-determined with respect to the current year's production and to use it as an explanatory variable in a supply equation. However, it is considered to be of such formidable importance to the sheep and wool industry that it was felt necessary to develop a model to explain it.

A common feature of the Dahlberg and B.A.E. supply studies cited above is the high explanatory power of improved pasture in explaining both greasy wool production and sheep numbers shorn. Data on the area of improved pasture in Australia are not available on an industry basis, however estimates by Gruen[3] suggest that over 70 per cent of the total is on sheep and sheep-cereal grain properties. Thus total area of improved pasture was used as a proxy for the effects of improved pasture on TNF_t. The B.A.E. study employed a moving average of the past five years' area of improved pasture. The reason for doing this was that they wished to use improved pasture as a surrogate for technology as well as a shift factor in its own right, and thus desired to smooth the effects of weather out of the series. In actual fact the smoothed series and the raw series are highly correlated and there was very little difference in regression results obtained using either one. Slightly higher t values were obtained using the smoothed series and so it was decided to conform with the B.A.E. study and adopt the five year average.

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3. See Gruen, F.H., "The Major Livestock Industries", p.402 in Moore, R. Milton (ed.), Australian Grasslands, A.N.U. Press, Canberra, 1970.

Watson has suggested that the recovery time for the Australian sheep population from the severe 1944-46 drought was about seven years.[4] However, it would be expected that somewhat less time for adjustment to weather conditions would be the case for less severe occurrences. To allow for the effects of past weather conditions on TNF_t, an Almon distributed lag was applied to the drought mortality index (DMI_t). The length of the lag was arbitrarily set at five years. The shape of the lag was something of a problem on which Watson's work could throw little light. Should the peak be set at t-1, at t-5 or somewhere in between? Experimentation with all three forms showed that by allowing the lag to peak in t-1 and thereafter to tail off to zero in t-6 (with its value in t being ignored), substantially better results were obtained in terms of R^2 and statistical significance.

Finally it would be expected that the size and reproductive capacity of the sheep population would be affected by farmers' expectations about future prices. To reflect price expectations, both an Almon distributed lag and the truncated distributed lag (t.d.l.) were tried (see Chapter 2). Lags of three or five years were tried separately with each and with a peak at the beginning, the middle or the end for the Almon case. The lags were applied to each of the following prices separately in an attempt to discover what prices were relevant to farmers' decision making concerning TNF_t: deflated wool prices, deflated price index of all sheep products, ratio of wool to wheat prices, ratio of wool to combined wheat and beef prices, ratio of sheep

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4. Watson, A.S., op.cit., p.15.

product prices to wheat prices, ratio of sheep product prices to combined wheat and beef prices. In addition to distributed lags, simple one year lags of these prices were also tried. In almost every case both the simple and partial correlation coefficients and the regression coefficients between price and TNF_t were negative. In the few cases where the expected positive regression coefficient was obtained, it was usually only a small fraction of its own standard error, indicating non-significance.

It was clear in every equation which was tried that improved pasture was the major explanator of TNF_t and that prices had practically no effect. Two questions which immediately arise are: what possible reasons could be advanced for this price insensitivity and what determines the area of improved pasture?

First, on the question of the lack of any price sensitivity it should be pointed out that Powell and Gruen and the B.A.E. were able to obtain positive price elasticities for wool supply. In the B.A.E. case, this was achieved with a simple one year lag on deflated price in a logarithmic equation. Their estimate of the supply elasticity, which was statistically significant at five per cent was +0.048 in the "best" of their estimated equations.[5] This compares favourably with the Powell and Gruen short run estimate of +0.051.[6] These elasticities are very small, but statistically they are significantly different from zero. Using a Nerlovian distributed lag, Powell and Gruen also calculated an "intermediate run" (five years) elasticity of +0.248. Dahlberg was

5. The best of their results for an equivalent sample period to the one covered by this study was considered to be those contained in column 1 of Table No. 11, p.64 of the B.A.E. study cited above.

6. See Gruen, F.H. and others, op.cit., pp.6-39.

considerably less successful and obtained negative elasticities for many of his models.

Both the B.A.E. study and Powell and Gruen used sheep shorn as dependent variable (Dahlberg used greasy wool produced) and both used price lagged one year as an explanatory variable.[7] It is quite possible that the number of sheep shorn would show some response to last year's price via the number of ewes mated. This would not be inconsistent with total sheep numbers being insensitive to long run price fluctuations in a situation where no clear trend is evident.[8] This is not to say that wool prices have not fluctuated during the sample period. The coefficient of variation of the deflated index was quite high at 52 per cent. However, it seems quite clear that these fluctuations have had virtually no effect on sheep numbers over time, improved pasture being an overwhelming explanator of TNF_t. It seems that the only price response in the sheep industry is a short run one of sheep shorn to last year's price. The mechanism for this adjustment is most probably through matings but this cannot be tested because of the simultaneous effects on matings of lamb prices.

If prices are ignored from the model to explain TNF_t and the only explanatory variables used are improved pasture and past weather conditions, the following estimates are obtained using OLS:

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7. Powell and Gruen make their model formally equivalent to a Nerlovian distributed lag system by including lagged output as an explanator. This enables them to obtain intermediate and long run elasticities as well as short run.

8. Neither the deflated nor undeflated wool price index exhibited any strong trend over the sam ple period. There was a weak downward trend in each.

$$TNF_t = 175.26 + \underset{(0.12)}{1.97^{**}}AP - \underset{(0.02)}{0.10^{**}}ALDIS$$

$$R^2 = 0.97$$

$$D\text{-}W = 0.62$$

where TNF_t is as defined above,

AP = average of area of improved pasture for five years previous to t,

ALDIS = variable obtained by applying an Almon distributed lag to the drought mortality index. The lag had a length of five years, a peak in t-1 and reached zero in t-6.

All estimated coefficients are of the correct sign and all are significant at one per cent. The R^2 is high but the D-W statistic indicates positive autocorrelation to be present. Application of the Hildreth-Lu procedure yielded a D-W statistic in the non-rejection region, the sum of squared residuals being a minimum at a value of ρ of 0.70. The resulting equation in terms of the original variables is:

$$TNF_t = 176.3 + \underset{(0.22)}{1.88^{**}}AP - \underset{(0.02)}{0.09^{**}}ALDIS$$

$$R^2 = 0.97$$

$$D\text{-}W = 1.87$$

The Almon weights calculated from the coefficient on ALDIS are as follows:

$$W_1 = 0.107, \quad W_2 = 0.103, \quad W_3 = 0.093, \quad W_4 = 0.069, \quad W_5 = 0.039.$$

The second question which was raised above is what influences improved pasture (AP)? It seems fairly unlikely that prices would be relevant since prices did not significantly affect TNF_t and since TNF_t and AP are highly correlated ($r = 0.96$). Experiments with various formulations on wool prices in regression equations to explain AP bore this out with non-significant negative coefficients. It was obvious from inspection that both TNF_t and AP were characterised by strong upward trends over time and since wool prices clearly have not been subject to an increasing trend, prices in themselves have not been a motivating factor. Even in a regression equation with a time trend included, the estimated price coefficient was negative and non-significant.

Donald[9] has pointed out the beneficial effects that pasture improvement has had on crop growing, particularly wheat. It is possible that the farmer is jointly motivated by (1) desire to lower his real per unit costs in the face of rising financial costs due to inflation and (2) desire to diversify, either for purposes of risk spreading or to take advantage of a profitable joint product, e.g. wheat. There was in fact a high correlation between wheat acreage and improved pasture. Gruen[10] has suggested that pasture improvement may in fact be

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9. See Donald, C.M., op.cit.

10. See Gruen, F.H., "Economic Aspects of Pasture Improvement in the Australian Wool Industry," Economic Record, Vol. XXXVI, No.74, April 1960, pp.230-233.

unprofitable unless the elasticity of demand for Australian wool is a lot higher than we think it is. If Gruen's analysis is acceptable, then the continued expansion of pasture improvement suggests that we are dealing with irrational wool growers. On balance it is felt that investigation of this feature of Australian wool growing is so complex as to warrant a separate study of its own and is outside the scope of this study.

Thus far, an equation has been estimated to explain the defined variable TNF_t. This variable represents the ceiling on the number of sheep that can be shorn in year t since it measures the size and reproductive capacity of the sheep population at the beginning of year t. In addition to TNF_t, it would be expected that climatic conditions, as represented by DMI_t, in year t would affect the number of sheep and lambs shorn during the year. The ratio of wool to meat prices in t are not expected to be relevant since it is considered that this will influence slaughterings but not shearings.

Following the reasoning above concerning the B.A.E. and Powell and Gruen elasticities, some response may be expected from wool prices in t-1. However, since it is believed that this response of shearings is via mating and since TNF_t already accounts for the maximum of mating, this response is expected to be absorbed in the coefficient on TNF_t. Thus little hope was held a priori concerning the success of wool prices in t-1. The results of the regression of the numbers of sheep and lambs shorn on TNF_t, DMI_t and wool prices in t-1 are as follows:

$$SLSH_t = 4.39 + \underset{(0.02)}{0.85^{**}} TNF_t - \underset{(0.02)}{0.09^{**}} DMI_t + \underset{(0.009)}{0.001} Pwl_{t-1}$$

$$R^2 = 0.99$$

$$D\text{-}W = 2.47$$

where $SLSH_t$ = number of sheep and lambs shorn in year t,

TNF_t = as defined above,

DMI_t = drought mortality index for year t,

Pwl_{t-1} = deflated B.A.E. index of wool prices in t-1.

It is clear that TNF_t and DMI_t are important determinants of $SLSH_t$. However, the failure of the wool price coefficient to achieve significance confirms a priori suspicions. The estimated coefficient of 0.001 yields an elasticity far too low to be considered practicable. The lack of significance of the wool price coefficient cannot be attributed to either multicollinearity or autocorrelation, the D-W statistic being in the non-rejection region and the highest inter-correlation coefficient for Pwl_{t-1} was -0.5 with DMI_t. This result suggests that the short term price effect is already allowed for in TNF_t. The estimated equation when wool price is omitted is:

$$SLSH_t = 4.74 + \underset{(0.02)}{0.85^{**}} TNF_t - \underset{(0.02)}{0.09^{**}} DMI_t$$

$$R^2 = 0.99$$

$$D\text{-}W = 2.44$$

The coefficients of this equation are not changed by the omission signifying the lack of importance of wool prices as an explanator. If this model is to be used for prediction, two points should be considered. Firstly, the equation to explain shearings includes the current value of DMI_t. While this is treated as an exogenous variable, there is no way of knowing it in advance and thus any forecasts concerning $SLSH_t$ must be conditional upon some assumed value of DMI_t.

Secondly, if the ultimate aim is to explain or forecast wool production, then some assumptions must be made about wool clip per sheep shorn. Fortunately, average fleece weights in Australia have been fairly stable over the sample period, the mean being 8.81 lb. per sheep with a standard deviation of 0.37 and a coefficient of variation of only 4.15 per cent. Thus if the mean is used as the best estimate of average fleece weight then wool production can be obtained by means of a simple identity:

$$WQ_t = SLSH_t \times MFW$$

where WQ_t = wool production during year t,

$SLSH_t$ = as defined above,

MFW = mean fleece weight.

In summary, a model has been developed here to explain sheep numbers shorn by reference to a variable which reflects the size and reproductive capacity of the sheep population. This size and fertility variable was found to be insensitive to past prices and to be determined largely by pasture improvement and past weather conditions. Since the variable reflected maximum mating it obscured the short run response to wool price via mating. The result is a model of high predictive and explanatory power, judging from the coefficients of multiple determination, but one which has the economically surprising omission of a price variable. The usefulness of the model presented here is going to be in studying the effects of drought on the sheep population and on wool production. If it is desired to study the effects of a change in wool prices, the B.A.E.-Powell and Gruen estimated short run price elasticity of +0.05 would seem to be the only one worth using.

SHEEP AND LAMBS FOR SLAUGHTER

In specifying a supply function to explain the number of sheep and lambs killed a number of factors were considered to be relevant on a priori grounds. Firstly and most importantly, the size and reproduction capacity of the sheep population at the beginning of the year would be expected to influence the numbers slaughtered during the year. The variable TNF_t reflects these characteristics of the sheep population and a function explaining TNF_t has been developed above. Secondly, the current period's prices for sheep and lambs for slaughter would be expected to influence farmers' decisions on whether to sell or retain livestock. Similarly, the current period's wool price would have the same effect but in the opposite direction. Finally, it was considered likely that current seasonal conditions (as measured by DMI_t)

would influence slaughterings. There is some uncertainty about the nature of the influence of DMI_t on slaughterings. A high value of DMI_t means that sheep and lambs may be dying on properties (or in the case of lambs, not being born) thus reducing the marketable numbers. On the other hand a high value of DMI_t may mean that farmers choose to market more animals than otherwise in order to avoid the costs of buying in feed.

The B.A.E. indices of prices received for sheep and for lambs were combined to form an index of prices received for all sheep. The weights used in combining the prices were the relative weights used by the B.A.E. for the index of all prices received by farmers. As pointed out above, to complete the system a demand equation must be specified to explain the current period's price. A principal explanator with an anticipated negative sign is the number of sheep and lambs slaughtered in the current period. Real personal disposable income per head ($YPDH_t$) was considered to be an important shift factor in the demand equation in so far as domestic demand is concerned. The quantity of carcass mutton and lamb exported in the period was proposed as a surrogate for the effects of export demand on current price.

The algebraic specification of the model as outlined above is:

$$SLK_t = \alpha_1 + \alpha_2 Psm_t + \alpha_3 Pwl_t + \alpha_4 TNF_t + \alpha_5 DMI_t \quad \text{(supply equation)}$$

$$Psm_t = \beta_1 + \beta_2 SLK_t + \beta_3 YPDH_t + \beta_4 MLX_t \quad \text{(demand equation)}$$

where SLK_t = number of sheep and lambs slaughtered in year t,

Psm_t = combined index of sheep and lamb prices in t, deflated by B.A.E. index of prices paid,

Pwl_t = B.A.E. index of price of wool in year t, deflated by B.A.E. index of prices paid,

TNF_t = size and fertility of the sheep population at the beginning of year t,

DMI_t = drought mortality index in year t,

$YPDH_t$ = real personal disposable income per head in year t,

MLX_t = quantity of carcass mutton and lamb exported in year t.

The following expectations were held regarding the signs on coefficients in the model:

$$\alpha_2 > 0 \;,\; \alpha_3 < 0 \;,\; \alpha_4 > 0$$

$$\beta_2 < 0 \;,\; \beta_3 > 0 \;,\; \beta_4 > 0$$

No prior expectations were held about the sign of α_5. The variables SLK_t and Psm_t are clearly endogenous being jointly interdependent. It seems fairly safe to treat Pwl_t as exogenous. The remaining four variables are all clearly pre-determined with respect to this model, MLX_t being mainly determined by overseas demand. The model as it stands is over-identified. Thus two stage least squares estimates of the coefficients are asymptotically unbiased but retain small sample bias, the bias however is expected to be smaller than that obtained by ordinary least squares.[11] Application of 2SLS yielded the following results:

$$SLK_t = -37{,}069 + \underset{(182)}{209.3}\ Psm_t + \underset{(75.1)}{281.6^{**}}\ TNF_t - \underset{(41.0)}{62.1}\ DMI_t - \underset{(41.8)}{55.8}\ Pwl_t$$

D-W = 1.34

$$Psm_t = 142.7 - \underset{(0.001)}{0.007^{**}}\ SLK_t + \underset{(0.07)}{0.14}\ YPDH_t + \underset{(0.17)}{0.25}\ MLX_t$$

D-W = 1.84

All coefficients about which prior expectations were held regarding sign have signs in accord with expectations. Only two coefficients have achieved statistical significance but there are reasons for this general lack of significance. First, in the supply equation the D-W statistic is such that the probability of there being zero autocorrelation is less than one per cent thus suggesting rejection of the null hypothesis. This may be causing the general lack of significance in the supply equation. Second, Goldberger suggests that the 2SLS method gives rise to larger variances than OLS,[12] thus efficiency may be a price for consistency.

Also, as might be expected in such a model, there is a high degree of intercollinearity. The correlation matrix is reproduced

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11. See Goldberger, A.S., op.cit., pp.357-364.

12. Ibid., p.362.

below with important simple correlation coefficients circled. Thus, the high degree of correlation between Psm_t and Pwl_t may be robbing either or both of significance. Furthermore, the relatively high degree of correlation between TNF_t and both Psm_t and DMI_t may also account for lack of significance in the supply equation. In the demand equation the high correlation between $YPDH_t$ and MLX_t and between SLK_t and both $YPDH_t$ and MLX_t is almost certainly the cause of the lack of significance of the coefficients on the latter two variables. Despite the lack of statistical significance, comfort can be taken from the fact that for every coefficient the t value exceeded unity. The above specification of the sheepmeat supply and demand model was the only one of the several tried which had both this property and all coefficients possessing the expected sign.

TABLE 4

Correlation Matrix for Variables in Sheep Supply and Demand Model

Variable	SLK_t	TNF_t	DMI_t	Pwl_t	$YPDH_t$	MLX_t	Psm_t
SLK_t	1.00	0.93	-0.22	-0.68	0.87	0.87	-0.78
TNF_t		1.00	-0.75	-0.63	0.88	0.75	-0.75
DMI_t			1.00	0.29	-0.18	-0.22	0.33
Pwl_t				1.00	-0.41	-0.59	0.84
$YPDH_t$					1.00	0.85	-0.54
MLX_t						1.00	-0.57
Psm_t							1.00

By way of comparison, Table 5 below shows the results of applying OLS to the model alongside the above 2SLS results. The R^2's obtained from the OLS model were 0.87 for the supply equation and o.68 for the demand equation. Note that despite reduced variances, the OLS estimated coefficients are generally lacking in significance as were the 2SLS estimates. Furthermore, the coefficient on Psm has an incorrect sign which is perhaps due to the greater bias in the OLS estimates. This may also explain the large differences in some of the other coefficients, viz those for DMI and Pwl.

TABLE 5

Comparison of OLS and 2SLS

Estimates of Coefficients of Sheepmeat Supply and Demand Model

Estimating Method / Independent Variable	Supply Equation		Demand Equation	
	OLS	2SLS	OLS	2SLS
SLK_t			-0.0047^{**} (0.00096)	-0.007^{**} (0.001)
TNF_t	203.7^{**} (29.1)	281.6^{**} (75.2)		
DMI_t	-31.4 (22.2)	-62.1 (41.0)		
Pwl_t	-10.1 (14.3)	-55.8 (41.8)		
$YPDH_t$			0.025 (0.093)	0.14 (0.07)
MLX_t			0.279 (0.189)	0.25 (0.17)
Psm_t	-5.0 (45.5)	209.3 (182)		
D-W	0.90	1.34	2.28	1.84

The negative coefficient on DMI_t suggests that the effect of a drought in the current year is to reduce the available supplies of sheep and lambs for slaughter. Using the 2SLS coefficients on Psm and Pwl, own and cross price elasticities of supply were evaluated at mean values of the variables. The own price elasticity was 1.02, the elasticity with respect to wool price was -0.31. These estimates are considerably higher than those obtained by the Monash team of 0.253 and -0.047 respectively.[13] However, they are essentially measuring different things. The Monash team's measures reflect the lags of adjusting livestock numbers to price changes while in this study these lags are already incorporated into the variable TNF_t. Thus the elasticities measured here are for supply out of a given stock and therefore the biological constraints are not reflected in the price coefficient.

In concluding this section it should be said that the 2SLS estimates of several of the coefficients of the model were extremely unstable under even slightly different specifications. This is partly a reflection of the fact that 2SLS takes into account all the information in the model including, for a particular equation, excluded pre-determined variables. Thus, if pre-determined variables are added or deleted, information is being added or deleted and this must affect the estimated coefficients. The particular specification presented here is preferred because it takes account of all influences that were arbitrarily thought to be important, all coefficients are of the expected sign and all

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13. See Gruen, F.H. and others, <u>op.cit.</u>, pp.6-39.

t values are at least greater than unity. The above is the only specification tried which possessed all of these properties.[14]

14. Other specifications which were tried include deleting Pwl_t or DMI_t from the supply equation, deleting MLX_t from the demand equation and deleting all of Pwl_t, DMI_t and MLX_t from the model leaving it exactly identified. Also tried was the addition of Pwl_t to the demand equation to reflect the fact that demand for sheep is likely to be affected by farmers buying sheep in response to wool price changes.

CHAPTER 7

SUPPLY FUNCTIONS FOR CATTLE AND CALVES FOR SLAUGHTER, DAIRY PRODUCTS, PIGS AND POULTRY PRODUCTS.

CATTLE AND CALVES FOR SLAUGHTER.

In specifying a model to explain the number of cattle and calves slaughtered,it was desired to specify a variable for the beef industry similar to TNF_t in the sheep industry, i.e. a variable which would reflect the size and fertility of the beef cattle population at the beginning of the year. As pointed out above this was not possible for the beef industry due to a change by the Statistician in definitions of beef and dairy cattle during the sample period. Accordingly, the approach used here is as follows. Define NC_t to be a variable representing beef cattle numbers and fertility at the beginning of t. It would be expected that NC_t would depend upon past prices and past seasonal conditions. It has been suggested[1] that prices and conditions from three to five years ago are important determinants of current numbers, the long lag being due to biological constraints on reproduction and fattening.

To reflect these lags and to reflect the fact that conditions five years ago are more important than current conditions, an Almon distributed lag was used with n=5 and with the quadratic peaking at t-5

1. See Gutman, G.O., "The Cattle Cycle," Quarterly Review of Agricultural Economics, Vol.III, No.1, January, 1950, pp.23-26.

and passing through zero at time t. Prices beyond t-5 were considered irrelevant and the values of the polynomial for those years were ignored. The lag was applied to both the deflated B.A.E. index of prices paid for cattle and the drought mortality index (here assumed to be a reasonable surrogate for climatic conditions in the beef industry).

It might be thought that improved pasture may be an important determinant of cattle numbers as it was for sheep numbers. However, estimates by Gruen suggest that the proportion of all improved pasture accounted for by the beef industry is very small.[2] It was nine per cent in 1965-66 having risen from three per cent in 1959-60. These percentages should be contrasted with 40 per cent for sheep and 30 per cent for sheep-cereal grain. Thus total area of improved pasture may be a poor proxy for area of improved pasture in the beef industry. Furthermore, improved pasture does not appear to be as important in the beef industry as it is in the sheep industry. From C.B.C.S. 1965-66 Classification of Rural Holdings, it can be calculated that the average area of improved pasture on sheep properties was 350 acres while on beef properties it was only 265 acres. There is probably some overlapping in these averages, properties running both sheep and beef cattle being counted in each. Nevertheless it seems clear that improved pasture, while on the increase, has not been as important to the beef industry as it has been to the sheep industry. Thus it was decided to exclude it from the relation to explain NC_t. This relation has the form:

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2. See Gruen, F.H., "The Major Livestock Industries", Ibid.

$$NC_t = A_1 + A_2\ ALPB + A_3 ALDI + u_t$$

where NC_t = hypothetical variable measuring size and fertility of cattle population at the beginning of year t,

ALPB = variable obtained by applying Almon distributed lag to deflated B.A.E.index of beef prices, length of lag was five years with peak in t-5,

ALDI = variable obtained by applying to DMI_t the same distributed lag as that used for ALPB,

u_t = random error term.

Now suppose a supply equation to explain the number of cattle and calves slaughtered with given herd size and fertility is specified as follows:

$$NCS_t = \alpha_1 + \alpha_2\ NC_t + \alpha_3\ Pb_t + \varepsilon_t$$

where NCS_t = number of cattle and calves slaughtered in year t,

NC_t = as above,

Pb_t = deflated B.A.E.index of prices received for cattle in year t,

ε_t = random error term.

If the substitution for NC_t is made in this equation the following is obtained:

$$NCS_t = (\alpha_1 + \alpha_2 A_1) + \alpha_2 A_2 ALPB + \alpha_2 A_3 ALDI + \alpha_3 Pb_t + (\alpha_2 u_t + \varepsilon_t)$$

Provided the u_t and ε_t satisfy the usual assumptions of least squares, the term $(\alpha_2 u_t + \varepsilon_t)$ will also satisfy these assumptions thus enabling estimates to be made with the usual properties. However, the coefficients on ALPB and ALDI will be the products $\alpha_2 A_2$ and $\alpha_2 A_3$ and it will not be possible to separate these into their components. Thus the actual values of the Almon distributed lag weights cannot be calculated. This is not really important however as ALPB and ALDI can always be calculated regardless, and since the primary aim of the model is to forecast slaughterings, the coefficients on these variables in the NCS_t equation are the important ones. This equation may be re-written as the following estimating equation:

$$NCS_t = \gamma_1 + \gamma_2 Pb_t + \gamma_3 ALPB + \gamma_4 ALDI$$

It would be arbitrarily expected that the signs of the coefficients in this equation are as follows:

$$\gamma_2 > 0 \,, \quad \gamma_3 > 0 \,, \quad \gamma_4 < 0$$

The current year's deflated cattle price (Pb_t) cannot be regarded as pre-determined with respect to the current year's slaughterings. Thus it was treated as endogenous and, as in the sheepmeat case, a demand equation was specified to explain it. Current slaughterings, current real personal disposable income per head and current exports of carcass beef and veal were considered to be important explanators. Thus the demand equation is very similar to that specified for sheepmeat. It has the following form:

$$Pb_t = \beta_1 + \beta_2 NCS_t + \beta_3 YPDH_t + \beta_4 BX_t$$

where Pb_t, NCS_t and $YPDH_t$ are as above,

BX_t = exports of carcass beef and veal in year t.

The following expectations were held regarding sign:

$$\beta_2 < 0\ , \quad \beta_3 > 0\ , \quad \beta_4 > 0$$

Again,as in the sheepmeat case, the complete supply and demand model is over-identified with all variables except NCS_t and Pb_t being considered pre-determined. The 2SLS estimates of the coefficients of the model are as follows:

$$NCS_t = 326.03 + \underset{(14.2)}{17.4}\ Pb_t + \underset{(3.5)}{10.5^{**}}\ ALPB_t - \underset{(1.7)}{2.9}ALDI_t$$

$$D\text{-}W = 0.92$$

$$Pb_t = 14.2 - \underset{(0.007)}{0.004}\ NCS_t + \underset{(0.04)}{0.10^{*}}\ YPDH_t + \underset{(0.03)}{0.01}\ BX_t$$

$$D\text{-}W = 1.32$$

There is a broad similarity in the quality of these results with those obtained for the sheepmeat model. All coefficients are of the right sign but there is a general lack of statistical significance in both equations. Autocorrelation, which is indicated to be present in both equations, may be contributing to this lack of significance. The correlation matrix, which is reproduced below, indicates that inter-correlation is also likely to be a contributing factor. This is especially true of the demand equation where inter-correlation between NCS_t and BX_t may be robbing both of significance.

The lack of significance of the coefficient on current price (Pb_t) in the supply equation cannot be attributed to multicollinearity since the correlation matrix shows that Pb_t is not highly correlated with either ALPB or ALDI. It is possible that the lack of significance is due to autocorrelation, though this cannot be said with certainty even in an OLS case, let alone in a 2SLS case. The short run supply elasticity

TABLE 6

Correlation Matrix for Variables in Beef and Veal Supply and Demand Model

Variable	NCS_t	ALPB	ALDI	$YPDH_t$	BX_t	Pb_t
NCS_t	1.00	0.87	-0.76	0.81	0.81	0.53
ALPB		1.00	-0.71	0.90	0.62	0.56
ALDI			1.00	-0.55	-0.54	-0.45
$YPDH_t$				1.00	0.62	0.74
BX_t					1.00	0.46
Pb_t						1.00

with respect to Pb_t, evaluated at mean values of the variables, was +0.348, which is a good deal higher than the Powell and Gruen estimate of +0.162. However, as pointed out for sheepmeat above, the Powell and Gruen elasticity is constrained by biological factors.

As an experiment, Pb_t was omitted from the supply equation making current supply solely dependent upon past factors, i.e. short run price expectations are assumed to be not relevant. This has the effect of breaking the interdependence of the two equations and their coefficients could then be estimated by OLS. When this was done, the resultant short run supply elasticity with respect to last year's price was estimated at +0.001 which seems to be far too low to be realistic. Thus it was felt that despite its lack of significance, Pb_t should remain in the model. It had the saving grace of a Student's t value which exceeds unity.

It might be thought that the multicollinearity deadlock in the demand equation could be broken by recourse to other estimates of the income elasticity of demand. Unfortunately, estimates such as those contained in the B.A.E. meat consumption surveys cited above are at the retail level and the model being considered here is really at the auction or saleyard level. However, even if the B.A.E. estimates are taken as the best available, it can be easily shown that it does not break the deadlock. For example, the true structural form of the demand equation should have quantity demanded depending upon price, thus:

$$NCS_t = \alpha_1 + \alpha_2 Pb_t + \alpha_3 YPDH_t + \alpha_4 BX_t$$

This equation is rearranged to make price dependent on quantity in the 2SLS model thus:

$$Pb_t = -\frac{\alpha_1}{\alpha_2} + \left(\frac{1}{\alpha_2}\right)NCS_t - \left(\frac{\alpha_3}{\alpha_2}\right)YPDH_t - \left(\frac{\alpha_4}{\alpha_2}\right)BX_t$$

Only in the case of perfect correlation will the estimated coefficients of these two equations be related in the manner suggested by the algebra. Extraneous estimates of income elasticity of demand will give information on the size of α_3. What is needed to break the deadlock in the model presented above is information on the size of $(\frac{\alpha_3}{\alpha_2})$. The only estimate of α_2 available is that from the model presented and this can hardly be considered extraneous.

Hence it was decided to retain the model in the form presented with the usual warnings about the presence of autocorrelation and multicollinearity.

DAIRY PRODUCTS

Logically, a supply study of the dairy industry should be composed of two parts: (1) domestic wholemilk supply and (2) supply of milk for manufacturing purposes (predominantly butter and cheese). In this study, however, it has been decided to adopt a broad approach and explain the supply of total wholemilk produced for all purposes. The main reason for this is a desire to keep the number of supply equations down as much as possible. Some degree of aggregation is necessary or else we would have a supply function for every single commodity and this would be clearly unmanageable. This particular aggregation is defensible, however, since suppliers of domestic wholemilk (commonly known as city milk suppliers), while licensed and to some extent controlled by the various metropolitan milk boards, are permitted to, and in fact do, sell to manufacturers milk produced over and above their required deliveries to the metropolitan milk board. Thus while they appear on the face of it to be independent of the manufacturing milk sector, in practice their returns and therefore their supply responses are interrelated with that sector.

A further point in relation to supply of dairy products concerns choice of a dependent variable. In other sectors there has been a key variable which farmers use for production decisions. For crops, this is the number of acres sown, for wool and beef it is the number of animals on hand. Following this approach for dairy products would lead to use of the number of dairy cows as the decision variable. Unfortunately, as pointed out above, consistent time series data are not available for this variable due to a change in 1964 in the format of questions asked on the statistical returns made by farmers to the Commonwealth Bureau of Census and Statistics. Since consistent data on total wholemilk production are available and since it was found to give reasonable results in regression equations, it was decided to adopt the production variable as the dependent variable rather than attempt to synthesise a consistent series for numbers of dairy cows.

As mentioned above, the supply of city wholemilk is controlled by metropolitan milk boards in the various capital cities. In most cases, this control amounts to something like a quota system with varying amounts of flexibility. The aim of the system is to ensure an adquate supply of fluid milk to meet the requirements of the population which is serviced by the particular board. The population of the capital city in each state accounts for a major part of the population which is supplied by the metropolitan milk boards. Thus, total capital city population, lagged one year, was tried as a proxy variable to represent the quota-type effect on supply of these metropolitan milk boards.

Annual consumption per head of capital city population has varied between 47.7 gallons and 63.1 gallons over the period 1946-47 to 1968-69. This variation suggests that capital city population is not a very good proxy for the quota effects on supply of the metropolitan milk schemes, at least not in a simple linear model. Its use can still be justified on the grounds that it is likely to be a dominant influence in the planning of the milk boards when allocating licenses and delivery requirements to producers. On a per head of total population basis, annual consumption was found to vary much less, between 29.7 gallons and 32.1 gallons over the same period. Thus total population lagged one year was also tried as a proxy variable to represent the effects of the metropolitan fluid milk schemes.

The increased use of improved pasture is thought to have been an important technological influence on supply. Data are only available on improved pasture on an Australia wide basis over all industries. Estimates made by Gruen[3] suggest that the dairy industry accounts for only a small proportion (11 per cent in 1965-66) of the total area of sown grasses and that this percentage is tending to fall over time (it was 14 per cent in 1959-60). This indicates that other industries are adopting pasture improvement at a slightly faster rate than the dairy industry. Nevertheless, on the assumption that movements in the total area would be highly correlated with movements in the area on dairy properties, the former was tried as a surrogate for technical change.

3. Gruen, F.H., "The Major Livestock Industries", op.cit., p.402.

It has been suggested that "improvement in farm management techniques and the application of technological knowledge to the farm enterprise" have been the principal sources of increased productivity in dairying.[4] A simple time trend might be suggested to represent the effects of these vague influences. However, the area under sown grasses and clovers is itself subject to such a strong time trend that it is felt to be suitable as a surrogate for these effects also.

Since the dependent variable in this study (production of wholemilk) is likely to be influenced by weather conditions in the same year, two separate surrogates for weather were tried. The first is the current value of the drought mortality index (DMI). Use of this index here is based upon two assumptions:

(a) that weather characteristics unfavourable for sheep are also unfavourable for dairying. This is a reasonably realistic assumption.

(b) that all weather which affects the sheep industry also affects the dairy industry. This assumption is not so realistic as a drought which is predominantly in the Australian pastoral zone will result in a high value for the index but will scarcely affect the dairy industry at all.

The second weather surrogate which was tried is based on milk yields per dairy cow. A reasonably significant upward trend was observed in this series[5] and it is assumed that aberrations from trend were purely

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4. Statement by Warne, R.K. in National Agricultural Outlook Conference, Contributed Papers, B.A.E., Canberra, 1971, p.F-8.

5. The squared coefficient of correlation between milk yield per dairy cow and time over the period 1946-47 to 1968-69 was 0.84.

attributable to weather. The residuals from the trend line were calculated and expressed as a percentage of the trend value. A high positive value for this variable is indicative of favourable weather conditions.

Finally, various price formulations were tried for the supply model. A basic formulation used simply the B.A.E. index of prices received for dairy products deflated by the B.A.E. index of prices paid by farmers and lagged one year, this being sufficient time for the national dairy herd and for production to begin to adjust to price changes.[6] To allow for the fact that total adjustment may not occur within one year, the t.d.l. formulation from Chapter 2 was also applied to the deflated price.

In addition to the deflated dairy products price index, regressions were run using the ratio of the dairy products price index to the B.A.E. price index for beef cattle, both lagged one year, and in t.d.l. formulations. This follows Powell's and Gruen's claim[7] that this ratio is a powerful explanator of the supply of dairy products. Also tried was the ratio of dairy products price index to the average of the B.A.E. indices of prices paid for sheep and lambs. This was tried in order to take account of any substitutability in production between dairying and fat lamb producing.

In all the regressions which were run, the estimated coefficient on the lagged, deflated price index had the expected positive sign and was

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6. The B.A.E. index reflects the various components of subsidy, domestic price, export price and wholemilk bonus payment that make up the returns to dairymen.

7. Powell, A.A. and Gruen, F.H., "Problems in Aggregate Agricultural Supply Analysis: I - The Construction of Time Series for Analysis", op.cit., p.135.

statistically significant at five per cent or better. However, in the cases where the price ratios were used, their coefficients were found to be positive but not significant at five per cent.

For the dairy/beef price ratio this lack of significance may be attributable to multicollinearity, since the inter-correlation coefficients between the ratio and both the population variable and the pasture variable were quite high at around -0.8. However, since the inter-correlation coefficients between the lagged, deflated price index for dairy products and both the population and pasture variables were even higher at around -0.9 and yet did not result in lack of significance, the multicollinearity hypothesis must be rejected as an explanation of the lack of significance on the dairy beef price ratio.

Similarly, the lack of significance on the dairy/sheepmeat price ratio cannot be attributable to multicollinearity since its inter-correlation coefficients were quite low at 0.2 to 0.3. In every regression equation containing price ratios, the D-W statistic indicated that autocorrelation was not a problem and thus it cannot be blamed for the lack of significance of the coefficients on the price ratios.

This indicates that rewards to alternative uses of resources may not be so important as the prices of dairy products themselves in determining wholemilk supply. This suggestion was re-inforced by regressions in which the t.d.l. formula was applied to the price ratios, the coefficients on all expected price ratios being statistically not significantly different from zero at five per cent. Observers close to the industry will not be surprised at this result as the high level of subsidisation and protection which the dairy industry receives must make alternative enterprises more risky and therefore less attractive even at competing relative prices.

The hypothesis of zero coefficient on the dairy/beef price ratio can be reconciled with Powell's and Gruen's finding of a highly significant partial transformation elasticity between the two enterprises. In the Powell and Gruen model, the coefficient on the price ratio is made up of a product of the partial transformation elasticity and the share of the competing product (in this case beef) in the total value of output of the two products.[8] While on an aggregate basis the total value of output of the two industries has been about the same in recent years (around $500m. in 1968-69), during the 1950's the gross value of dairy production was about 50 per cent greater than that of the beef industry; making the share of beef in the total output about two fifths.

Furthermore, it could be argued that relative sizes on an aggregate basis are not relevant for considerations of likely movements between the two enterprises but rather relative shares in output on farms where some substitution in production has occurred.[9] There is some evidence to show that where properties, which are principally engaged in dairying, carry beef cattle, the numbers of beef cattle carried are very small compared to numbers of dairy cattle.[10] This

8. See Gruen, F.H. and others, Long Term Projections of Agricultural Supply and Demand, Australia 1965 to 1980, op.cit.,pp.6-24 and 6-25.

9. This would effectively exclude the northern beef producing areas of Western Australia, Northern Territory and Queensland from consideration. Movement between beef and dairy production in these areas is likely to be impractical.

10. Commonwealth Bureau of Census and Statistics, Classification of Rural Holdings By Size and Type of Activity, Bulletin No.7, 1965-66, op.cit., shows that of 49,334 holdings classified to "milk cattle", 30,131 of them had no beef cattle at all and another 10,779 had between nought and ten (i.e. 1-9) beef cattle.

would cause the beef share in total value of output of the two products to be very small and would therefore explain the lack of significance of the coefficient on the dairy/beef price ratio.

In all regressions in which improved pasture was used, its estimated coefficient had a negative sign and was not significant. Logically one would expect that increased use of improved pasture would enable productivity gains such that more milk would be produced at a given price. Indeed, the simple correlation coefficient between production and the pasture variable was high and positive, however, the partial correlation coefficient, with other variables held constant, was negative. It is possible that the pasture variable does not accurately represent the effect of technical change in the dairy industry.

However, a more likely explanation of its poor performance is to be found in the high degree of multicollinearity existing between the population variable and the pasture variable. There is a strong time trend evident in both of these variables and it seems reasonable to suppose that effects of technical progress and diffusion of new techniques such as improved and irrigated pasture are also likely to be characterized by a trend over time. It seems possible then that the strong time trend element in the population figure accounted for technical change, leaving only a coincidental negative relationship for the pasture variable.

It could also be argued that in view of the subsidisation and protection which the industry receives, it would be reasonable to expect a general lack of incentive to adopt new techniques. This would lead one to expect a coefficient on pasture that is not significantly different from zero, as was obtained. However, the opposite view is also possible, namely that a high level of subsidisation and protection creates a secure environment in which producers are more willing to take risks on new techniques, especially those involving heavy capital expenditure. On balance it is felt that the multicollinearity argument is more reasonable.

On the assumption that the multicollinearity will continue, i.e. that population (either total or capital city) will continue to be characterised by a time trend which is also a feature of technical progress in the industry, improved pasture was omitted from the model. In Tables 7, 8 and 9 below a comparison is made of regression results of models using different population variables and different weather surrogates with improved pasture omitted.

Comparisons of the performance of the two population variables in Table 7 show that there was a generally better fit (higher R^2) for models containing capital city population (CPN) than for models containing total population (TPN). The estimated coefficient on the population variable was always positive and highly significant, regardless of whether CPN or TPN was used. In addition to its generally poorer fit, also operating against TPN was the fact that in two models where it was used, the last two models in Table 8, the Durbin-Watson statistic indicated positive autocorrelation to be present. However, this may be due to misspecification of the models. Similarly, in two models in Table 7 in which CPN was used, the Durbin-Watson statistic is indicative of negative autocorrelation. It was felt that the

Hildreth-Lu procedure should only be resorted to if alternative specifications do not give satisfactory results. Such specifications are presented in the Tables and therefore the procedure was not used in this section. On balance, the choice between the population variables is a marginal one, the decision being best left until the effects of the weather variables have been considered.

TABLE 7

Summary of Results of Regressions to Explain Supply of Wholemilk - Australia, 1946-47 - 1968-69

Explanatory Variable	Regression Coefficients and Standard Errors			
E(Pd)	5.7* (2.6)	7.7** (2.1)		
Pd_{t-1}			6.7* (3.0)	9.1** (2.4)
TPN_{t-1}	0.2** (0.02)		0.1** (0.02)	
CPN_{t-1}		0.2** (0.02)		0.2** (0.02)
R^2	.86	.91	.86	.92
D-W	1.98	2.57	1.96	2.59

where:

Pd_{t-1} = The Bureau of Agricultural Economics' dairy products price index deflated by the Bureau's index of prices paid by farmers, lagged one year.

E(Pd) = The index of expected value of Pd obtained using the t.d.l. formula for ω = .3 and n = 3. These values of ω and n were found to give a value of E(Pd) which resulted in best fits in all regression equations.

TPN_{t-1} = Total population of Australia at 30 June in year t-1.

CPN_{t-1} = Total capital city population of Australia at 30 June in year t-1.

Comparisons between Table 7 and Tables 8 and 9 indicate that only very slightly better explanation (higher R^2) is obtained by inclusion of either of the surrogates for weather. The estimated coefficients on the weather variables all had signs in accordance with expectations and many were significant at five per cent or better. The weather surrogate constructed from milk yields per dairy cow (YD) was particularly successful in this regard but when used in conjunction with TPN gave rise to positive autocorrelation. The coefficient on the drought index (DMI) only achieved significance in one model, namely, when used in conjunction with CPN (Table 9). Thus it is seen that CPN performs better than TPN when a weather surrogate is added to the equation. The choice between them then hinges on whether or not it is thought desirable to include and quantify the effects of weather.

If it is considered desirable to include weather as an explanatory variable, the "best" models would seem to be represented by columns one, three and four in Table 9. All coefficients in these models are significant and of the anticipated sign, the explanation is high ($R^2 > 0.9$) and the models are free of any indication of autocorrelation. If slightly less explanation is sufficient and if inclusion of weather is not required, statistically useful models can be found in columns one and three of Table 7. Both of these feature reasonable fit ($R^2 = .86$), statistically significant coefficients and absence of any indication of autocorrelation. They also both employ TPN as the population variable.

Since one of the aims of this study is to simulate a drought and study its effects on the rural economy, it was thought desirable that weather be included, and especially since it yielded such statistically useful results. Therefore column one in Table 9 is selected as the best supply function for dairy products. Column one is preferred to columns three and four because for the latter two, the D-W statistic is on the borderline of non-rejection of the hypothesis of zero autocorrelation while for column one the D-W statistic is clearly in the non-rejection region.

TABLE 8

Summary of Results of Regressions to Explain Supply of Wholemilk - Australia, 1946-47 - 1968-69.

Explanatory Variable	Regression Coefficients and Standard Errors			
DMI_t	-0.7 (0.4)	-0.6 (0.4)		
YD_t			7.7** (1.7)	7.3** (1.7)
E(Pd)	5.8* (2.5)		6.0** (1.8)	
Pd_{t-1}		6.4** (2.9)		6.3** (2.2)
TPN_{t-1}	0.2** (0.03)	0.1** (0.02)	0.2** (0.02)	0.1** (0.02)
R^2	.87	.87	.93	.92
D-W	1.62	1.66	0.94	1.01

where:

DMI_t = drought mortality index for year t,

YD_t = percentage deviation from trend of average milk yield per dairy cow in year t, other variables as defined above.

TABLE 9

Summary of Results of Regressions to Explain Supply of Wholemilk - Australia, 1946-47 - 1968-69.

Explanatory Variable	Regression Coefficients and Standard Errors			
DMI_t	-0.7^{*} (0.3)	-0.6 (0.3)		
YD_t			4.7^{**} (1.6)	4.4^{*} (1.6)
E(Pd)	7.7^{**} (1.9)		6.8^{**} (1.8)	
Pd_{t-1}		8.3^{**} (2.2)		7.8^{**} (2.1)
CPN_{t-1}	0.2^{**} (0.02)	0.2^{**} (0.02)	0.2^{**} (0.02)	0.2^{**} (0.02)
R^2	.93	.93	.94	.94
D-W	2.31	2.27	1.57	1.59

The definition of the variables is given in Tables 7 and 8.

PIGS

Introduction

Production of pigs in Australia has traditionally been a sideline operation on dairy farms, the skim milk retained on the farms after separation being used as a principal feed source. However, two important changes to the nature of the industry have been taking place. First, there has been a great expansion of pig raising in grain producing areas, associated with the 1960's boom in grain production, especially wheat. It is impossible to pinpoint when this expansion began because of lack of data, however a study by Janet Hill[11] suggests that for New South Wales, the situation changed from a predominance of pig-dairying mix to a predominance of pig-grains mix between 1955-56 and 1964-65.

The reasons for this changing structure are twofold. Grain producers have found it profitable to keep some pigs and feed them on grain produced on the farm. This is likely to become more important if wheat quotas result in growers carrying stocks of grain that the Wheat Board will not accept. Secondly, there has been an increasing trend towards delivery of wholemilk by dairy farms to butter and cheese factories rather than separate the milk on the farm. According to estimates by Pender and Erwood,[12] this has reduced the quantity of skim

11. Hill, Janet, R., "The Capacity of the N.S.W.Pig Market to Absorb Possible Increases in North Coast Pig Production", Australian Journal of Agricultural Economics, Vol.12, No.2, Dec. 1968, p.36.

12. Pender, R.W. and Erwood, Vivienne, "Developments in the Pig Industry and Factors in the Australian Meat Market Affecting Demand for Pigmeat", Quarterly Review of Agricultural Economics, Vol.XXIII, No.1, Jan. 1970, pp.19-34 and particularly p.20.

milk available as feed.

The second major structural change concerns the emergence of "pig specialists". These are typically large, intensive enterprises utilising grains and prepared concentrates for feed and employing modern management techniques. A recently published B.A.E. survey of the Australian pig industry indicates that these large specialist holdings have accounted for only 4.3 per cent of all pig slaughterings in recent years.[13] However, their rate of growth has been so fast that this percentage is sure to rise rapidly. It is noteworthy that on these large specialist properties, the B.A.E. survey reveals grains to be the most important feed used, being used both in unmixed form and as part of a complete ration mix. These developments make it clear that the future of the pig industry is going to be closely related to that of grain growing.

All of the studies cited have noted a trend towards larger holdings of pigs as dairy properties with typically small holdings drop out of the industry and as large, specialist holdings emerge. This trend is attributed to improved management techniques and economies of larger scale operation.[14] Both of these improvements in efficiency have important consequences for supply analysis in that they will result in greater output at a given price, thus resulting in a shift in the supply curve.

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13. Bureau of Agricultural Economics, "Pig Raising in Australia: An Economic Survey, 1967-68 to 1969-70: Preliminary Results", Quarterly Review of Agricultural Economics, Vol. XXV, No.2, April 1972, pp.147-17

14. See Hill, Janet, op.cit., p.38 and Pender, R.W. and Erwood, Vivienne, op.cit., pp.23-24.

The Supply Model

In her N.S.W. study Janet Hill estimated supply responses for dairying regions separately from grain growing regions.[15] She obtained useful results using sow numbers as a dependent variable but unfortunately comparable data to that used by her for N.S.W. is not available for other states. This prevents application of her two region model on an Australia wide basis. In view of the obvious importance, both now and in the future, of the pigs-grains mixture, it was decided to adopt Hill's grain region model for the aggregate supply function for the period being studied. While this approach ignores the pigs-dairying mixture, which was important for the first one third of the period and is still significant, it can be justified on two grounds. First, the model is forward looking in the sense that pig raising and grain growing seem likely to become overwhelmingly more important as an enterprise mix than pig raising and dairying. Second, attempts which were made to allow for the pigs-dairy mix by including the pigs/dairy products price ratio as an explanator ran foul of inter-correlation between the price variables.

Hill's grain region model of supply used three variables in explaining sow numbers at the beginning of period t. The ratio of pig prices to coarse grain prices in t-1 was used to reflect the relative profitability of pig raising as opposed to grain growing. The N.S.W. wheat acreage for the previous season was used to reflect the importance of the association between pig raising and increased wheat acreages and

15. See Hill, Janet, op.cit., pp.37 and 38.

also presumably as a measure of the potential for feeding wheat to pigs.[16] Finally, time was included as a catch-all for the trend towards better management and larger holdings.

When applied to the N.S.W. grain region, this model gave quite satisfactory results in terms of R^2, tests of significance of coefficients and Durbin-Watson test for autocorrelation. In applying the model to Australia wide data two slight alterations were made. First, instead of using the pigs/coarse grains price ratio, the pigs/all grains price ratio was used to reflect the relative profitability of pig raising as opposed to grain growing. The indices used were B.A.E. indices of prices received for pigs and for all grains. Second , rather than use wheat acreage in t-1, total grain acreage in t-1 was used to reflect the potential for grain feed for pigs. This permitted the association of pig raising with other grains besides wheat to be taken into account, principally with grain sorghum in Queensland, with barley in South Australia and with oats in Western Australia.

The results of running the regression of this model for Australia as a whole were as follows:

$$NSOW_t = 72.75 - \underset{(0.34)}{0.0004}(Pp/Pg)_{t-1} + \underset{(0.002)1}{0.005^*}TGA_{t-1} + \underset{(1.7)}{3.4^*}TIME \quad \ldots (1)$$

$$R^2 = 0.85$$

$$D\text{-}W = 1.67$$

16. Due to lack of data for the early years of the sample period, it has been impossible to obtain reliable and consistent estimates of the quantity of grain fed to pigs in Australia. Were these estimates possible, a more detailed model of the cereals-pig raising complex may have been specified.

where:

$NSOW_t$ = sow numbers at the beginning of year t, thousands.

$(Pp/Pg)_{t-1}$ = ratio of pig prices to prices for all grains during year t-1.

TGA_{t-1} = total area under all grains in year t-1.

TIME = time, base 1945-46 = 0.

The Durbin-Watson statistic is in the region of non-rejection of the hypothesis of zero autocorrelation and the R^2 is reasonably high. The negative coefficient on the price ratio is unexpected but it is thought that this may be attributable to intercorrelation between the price ratio and time. The inter-correlation coefficient was 0.81. It seems that the time trend may be robbing the price ratio of any positive influence the latter might have. This is born out by the fact that the simple correlation coefficient between NSOW and the price ratio was +0.65, whereas the partial correlation coefficient between them, after allowing for the effects of time, was negative at -0.31.

It is surprising that Hill did not come up against this problem. In an attempt to overcome it for the national model, it was assumed that Hill's estimate of the price elasticity of supply of 0.7 for N.S.W. could be applied nationally. When applied at the average levels of the price ratio and NSOW, the coefficient on the price ratio was estimated to be 1.42. This estimate was used in an attempt to overcome the multicollinearity. A new dependent variable was defined as $NSOW_t - 1.42(Pp/Pg)_{t-1}$ and the regression was run of the redefined dependent variable on the two remaining independent variables. Unfortunately the results of this regression were poor, with R^2 being only 0.54 and the coefficient on time being negative and not significant. Since all of the original variables were characterised by strong trends, it was felt that little would be lost in the specification if time were excluded,[17] since its effects on the dependent variable would still be being felt via the remaining two explanatory variables. The results of the regression with time excluded were as follows:

$$NSOW_t = 5.86 + \underset{(0.21)}{0.56^{*}}(Pp/Pg)_{t-1} + \underset{(0.001)}{0.007^{**}}TGA_{t-1} \quad \ldots\ldots (2$$

$$R^2 = 0.83$$

$$D\text{-}W = 1.86$$

where the variables are as specified below.

These results appear to be quite satisfactory with both coefficients having the expected sign and being significant at five per cent or better, the Durbin-Watson statistic is again in the region of non-rejection of the hypothesis of zero autocorrelation. These results enable prediction of sow numbers at the beginning of the year. Actual supplies of pigs during the year will depend not only upon sow

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17. It should be remembered that time is a catch-all for improved management, larger scale of operations etc. which are particularly associated with the emergence of large pig specialists. Should the time trend in the price ratio and the grains acreage be halted but the trend towards large, specialist holdings continue then the model would have to be reformulated.

numbers at the start of the year but also upon the size and number of litters born during the year. Presumably producers have little say in the size of litters but since pigs are capable of more than one litter per year, the number of pigs available for marketing can be influenced to some extent by controlled mating.

It seems likely that the higher the current price for pigs, the more producers will attempt to increase supplies by increasing matings. This raises the problem of contemporaneous variables. Since there is virtually no foreign trade in pigs or fresh pork, the current price for pigs is heavily influenced by the number of pigs coming onto the market and vice versa, the equilibrium price and quantity being decided by the interaction of both supply and demand functions. It was therefore necessary to specify not only a function explaining the number of pigs coming onto the market given a certain number of sows but also a function for the demand for those pigs dependent upon price. The following a priori model was specified:

$$NPS_t = \alpha_1 + \alpha_2 NSOW_t + \alpha_3 RPP_t \quad \text{(Supply Function)}$$

$$RPP_t = \beta_1 + \beta_2 YPDH_t + \beta_3 NPS_t \quad \text{(Demand Function)}$$

where NPS_t = total number of pigs slaughtered in t.

$NSOW_t$ = as above.

RPP_t = deflated B.A.E. index of prices received for pigs in t.

$YPDH_t$ = personal disposable income per head of population in t, deflated by the Consumer Price Index.

It would be expected, a priori, that the coefficients would have the following signs:

$$\alpha_2 > 0, \quad \alpha_3 > 0, \quad \beta_2 > 0, \quad \beta_3 < 0 .$$

The variable $NSOW_t$ can be taken as predetermined with respect to the current year, since it measures the number of sows at the beginning of the year. Also $YPDH_t$ can be regarded as exogenously determined with respect to the farm sector. NPS_t and RPP_t are both clearly interdependent endogenous variables. This model is exactly identified and both 2SLS and ILS give identical results. The 2SLS estimates of the coefficients are as follows:

$$NPS_t = -1{,}827 + \underset{(4.4)}{11.1^{*}} RPP_t + \underset{(0.9)}{13.8^{**}} NSOW_t$$

$$\text{D-W} = 2.74$$

$$RPP_t = 66 - \underset{(0.007)}{0.04^{**}} NPS_t + \underset{(0.03)}{0.14^{**}} YPDH_t$$

$$\text{D-W} = 2.55$$

All estimated coefficients are of the expected sign and are statistically significant at five per cent or better. Both D-W statistics are indicative of negative autocorrelation. However, in view of the fact that little is known of the effects of autocorrelation in a simultaneous system, it was decided not to tamper with the estimates. At mean values of the variables, the elasticity of slaughterings with respect to current price was calculated at 0.59. There are no other studies with which this figure can be compared, however it is much lower than the above estimated elasticity of 1.02 for sheep and lamb slaughterings. It is thought that this may be due to the fact that pig raising continues to be mainly a sideline operation and returns to pig raising possibly do not constitute a major proportion of total returns.[18] Thus a large change in price of his sideline operation may be necessary to attract the farmer's attention and a production response.

POULTRY PRODUCTS

In terms of gross value of annual production, the poultry industry is larger than either the fruit industry or the coarse grains industry. The poultry industry has been subject to some very great changes over the past decade and these together with a general lack of data make estimation of a supply function for poultry products very difficult. These difficulties, and the lack of data have been remarked on by Gruen and others.[19] The major changes that have taken place involve specialisation, emergence of larger scale, intensive producers and increasing use of prepared feeds.

In the immediate post-war years, most raising of chickens for meat was done on properties which were principally engaged in egg

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18. The B.A.E. Survey indicated that on average 31.4 per cent of gross receipts were attributable to pig raising.

19. Gruen, F.H. and others, op.cit., pp.6-89 to 6-98.

production, often mixed with other enterprises such as dairying. The past decade has seen the emergence of large scale specialist producers in both the egg production side and, most importantly, in the production of chickens for meat. A consequence of the improvement in egg producing efficiency has often been over-production and this has resulted in the establishment of egg marketing boards in each State and a Federal producer licensing system.

Statistics are available on the number of eggs handled by the marketing boards but it has been estimated that this only accounts for between 45 and 55 per cent of total production due to the existence of unlicensed "backyard" producers.[20] There are no statistics available on flock numbers and statistics on poultry hatchings and slaughterings have only been available since 1965-66. Faced with this situation, the Monash team used recorded egg production as dependent variable in a supply function for eggs. As explanatory variables they used an index of egg prices and an index of the cost of feed wheat. The regression coefficients had the expected signs and were highly significant;however the degree of explanation was poor ($R^2 = 0.5$) and they rejected the estimated equation for use in projections.[21] Due to lack of data they were not able to estimate a supply function for poultry meat.

While egg production has exhibited an upward trend over time it is in the meat section of the industry that the most marked growth

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20. See Gruen, F.H. and others, <u>op.cit.</u>, pp.6-89.

21. <u>Ibid.</u>, pp.6-95.

has occurred. Over the four years since the poultry slaughterings figures were available to 1968-69, the number of chickens slaughtered for human consumption increased by 43 per cent. In view of the lack of data on poultry slaughterings for earlier years it was decided to attempt to develop a supply function for poultry products as a whole rather than separate the industry into an egg producing part and a meat producing part. For this purpose, the C.B.C.S. series of gross value of production of poultry products was chosen as a dependent variable. To obtain a measure of the quantum of production, the gross value was deflated by the B.A.E. index of prices received for poultry products in the same year.

In view of the many factors that have been operating to shift the supply curve outwards over time, it was decided to use a time trend as a surrogate shift factor in the supply function. The B.A.E. index of prices received for poultry products was deflated by the B.A.E. index of prices paid and lagged one year to represent the price variable in the supply function. The regression estimates for this function are as follows:

$$QCH_t = 288.4 - \underset{(0.38)}{1.567^{**}} Pch_{t-1} + \underset{(0.77)}{0.636} \, TIME$$

$$R^2 = 0.80$$

$$D\text{-}W = 1.24$$

where QCH_t = quantum of poultry production in year t,

Pch_{t-1} = deflated index of prices received for poultry products in t-1,

$TIME$ = arithmetic time trend, 1945-46 = 0

The lack of significance of the time coefficient is possibly due to the autocorrelation indicated by the Durbin-Watson statistic. It could also be due to multicollinearity since the coefficient of inter-correlation between Pch_{t-1} and TIME was -0.85. The simple correlation coefficient between QCH and TIME was 0.81, suggesting that there is a substantial trend element in the dependent variable. The negative regression coefficient on price, despite its statistical significance, cannot be thought to have any economic importance. The most likely explanation of this result is that technical factors are shifting supply outwards more rapidly than is accounted for by the simple time trend, and at a more rapid rate than that at which demand is growing. Hence, prices are tending to fall over time but because supply conditions are dominated by technical factors, the declining prices are not causing any significant supply response in the same direction.

In view of the rapid rate of technological change that has taken place and continues to take place in the industry, it was decided that it would be impractical to attempt to further refine the model in order to obtain a more meaningful price coefficient. Instead, an attempt was made to better reflect the technical changes by use of a semi-log time trend thus:

$$\text{Log } QCH_t = \text{Log } A + TIME \text{ Log } B$$

which when written in arithmetic terms becomes,

$$QCH_t = A.\ B^{TIME}$$

This particular formulation has the property of a constant percentage rate of change per year (given by B-1 times 100). Thus in a growing series such as QCH, the absolute size of the annual increase becomes larger each year, rather than remaining constant as it does in the arithmetic formulation.

When the semi-log formulation was applied to the data for the whole sample period it yielded the following results:

$$\text{Log } QCH_t = 1.9551 + \underset{(0.0016)}{0.0108^{**}} \text{TIME}$$

$$R^2 = 0.66$$

$$\text{D-W} = 0.29$$

which when rewritten becomes:

$$QCH_t = 90.18(1.025)^{\text{TIME}}$$

This indicates an annual average rate of growth of 2.5 per cent which seems rather low in the light of the growth rate in slaughterings in recent years. When the semi-log formulation was applied to data for the ten years 1959-60 to 1968-69 it yielded a much higher annual rate of growth of 6.5 per cent and a higher R^2 of 0.95.

The complete equation was:

$$QCH_t = 44.93(1.065)^{\text{TIME}}$$

$$R^2 = 0.95$$

$$\text{D-W} = 1.84$$

Since it is believed to be a better reflection of current conditions in the poultry industry, this equation was selected for use in prediction and forecasting.

CHAPTER 8

FARM COSTS

Introduction

In the Australian National Accounts (A.N.A.), the Commonwealth Statistician publishes statistics on the gross value of farm production and farm costs. Aggregate farm income is obtained by subtraction. No attempt is made to appropriate farm costs on an industry basis thus avoiding the necessity to make arbitrary decisions concerning the apportionment of joint costs. In this study it was decided to follow the Statistician's lead in this matter and no attempt is made here to allocate joint costs.

From 1948-49 to 1966-67 five separate items of farm cost were distinguished in the Australian National Accounts. They were: (1) marketing costs, (2) seed and fodder costs, (3) depreciation, (4) wages and salaries and (5) other costs. From 1967-68, these items were re-arranged slightly to give the following: (1) marketing costs, (2) seed and fodder costs, (3) depreciation, (4) wages, net rent and interest paid and (5) other costs. Table 10 below shows the relationship between the two classifications. It is clear that if items (4) and (5) are combined into one item called "other costs, not elsewhere included (n.e.i.)", then the classifications of farm costs would be consistent on both sides of 1967-68. It was decided to do this rather than attempt to separate wages and salaries out of item (4) in later years.

TABLE 10

Comparison of Farm Costs Breakdown Pre and Post 1967-68

Item No.	Pre 1967-68	Post 1967-68
(1)	Marketing Costs →	Marketing Costs
(2)	Seed and Fodder Costs →	Seed and Fodder Costs
(3)	Depreciation →	Depreciation
(4)	Wages and Salaries →	Wages, Net Rent and Interest Paid
(5)	Other Costs →	Other Costs

The effect of this aggregation is that the item other costs n.e.i. is equal to half of total costs. Thus it becomes a large item, representing several different aspects of farm costs. Explanation and prediction of these different aspects might well be facilitated by a more disaggregated approach. However, the unavailability of data prevented this.

As pointed out above, consistent time series on farm costs were first published in 1948-49. Estimates for 1947-48 are available from National Income and Expenditure 1951-52 and from a paper by Youngman.[1] These estimates were made on the same basis as the estimate made and published by the Statistician in the A.N.A. and thus are comparable with the A.N.A. figures for early years. However, over time the Commonwealth Statistician has progressively revised the A.N.A. figures for 1948-49 onwards. As the revised figures for early years ar considered to be more accurate and certainly are more comparable with

1. Youngman, D.V., "The Estimation of Farm Income", paper read to Sectio G of the Australian and New Zealand Association for the Advancement o Science, Sydney, August, 1952, p.24.

later years, they were adopted in this study. As the cost figures for 1947-48 have never been revised, the estimates for this year are not comparable with those from 1948-49 onwards and so it was decided to om: to omit 1947-48 from the sample period for the cost equations. This meant that the sample period for the cost equations (1948-49 to 1968-69) was two years less than the sample period for the supply functions (1946-47 to 1968-69).

A further point in relation to the data concerns the period of measurement. Since the intention of this study is to use the cost equations in connection with supply functions to explain farm income, it is necessary that the data relate to the same time unit in both areas. The rural year on which all the supply functions are based ends on 31 March in the official statistics. The A.N.A. cost figures are all given on a normal financial year basis ending on 30th June.. It was decided to adjust the A.N.A. cost figures to a rural year basis by simply assuming an even spread of costs throughout the year and interpolating for the one quarter difference between rural years and financial years. Thus the costs for year t were estimated by taking a quarter (¼) of the figure for t-1 and adding to it three quarters ($\frac{3}{4}$) of the figure for t. By assuming that the 25 per cent of the t-1 figure relates to the June quarter of year t-1 and that the 75 per cent of the year t figure relates to the September, December and March quarters for year t, the figures are thus adjusted to a rural year basis. To the extent that farm costs are characterised by a seasonal pattern these figures will be slightly inaccurate, but they will at least be more representative of costs for a rural year than the raw, unadjusted data.

There has been some criticism in the past concerning the accuracy of the cost figures published in the A.N.A.[2] The main point of the criticism has been that very little data is actually obtained from statistical collections from the farm sector itself. Most of the cost items are estimated by reference to freight rates, fertiliser prices, farm debt levels and other indicators. Some use is also made of B.A.E. farm survey data. The figure used for depreciation is that allowable for tax purposes which is inflated by special tax concessions for farmers. If the aim of this study was to develop a model to explain the purchasing power of farmers then these criticisms might have to be bowed to and the cost figures might need to be re-examined. However, a principle aim of this study is to provide a model to explain the Statistician's published estimate of farm income, since it is this published figure which is used as an exogenous variable in various econometric models of the Australian economy. Thus it was decided that, apart from the adjustment to a rural year basis, the published cost figures would be accepted at their face value.

The B.A.E. has available detailed indices of prices paid by farmers for a wide range of cost items. The level of disaggregation of the indices is such that by grouping selected items with the weights used by the B.A.E. in arriving at its aggregate prices paid index, indices can be arrived at which correspond fairly closely to each of the four main

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2. See Youngman, D.V., op.cit., p.6, and Gruen, F.H., "Australian Agriculture and the Cost-Price Squeeze", pp.322-325 in Arndt, H.W. and Corden, W.M. (eds.), The Australian Economy, F.W.Cheshire, Melbourne, 1963.

cost items obtained from the A.N.A.[3] The relationship between the B.A.E. indices and the A.N.A. items is shown in Table 11 along with the weights used for the groupings.

TABLE 11

Relationship Between B.A.E. Indices of Prices Paid and Cost Items Obtained from A.N.A.

B.A.E. Weight[a]	B.A.E. Index	A.N.A. Cost Item
856	Marketing Expenses	Marketing Costs
864	Seed and Fodder	Seed and Fodder Costs
601	Fertiliser	Other Costs, n.e.i.
219	Chemicals	
644	Fuel and Electricity	
170	Containers	
670	Replacement Parts	
48	Other Supplies	
2,174	Wages	
1,793	Services and Overheads[b]	
835	Machinery and Plant	Depreciation
365	Motor Vehicles	
239	Fencing Materials	
522	Building Materials	

a. The B.A.E. weights are on a base of 10,000

b. Services and Overheads is a B.A.E. sub-group, covering such items as rent, interest, insurance and rates and (indirect) taxes.

There are two ways in which the prices paid indices could be used in models to explain farm costs. First, they could be employed to deflate the A.N.A. cost items yielding estimates of "real" costs.

3. The weights are given in B.A.E.,"Indexes of Prices Received and Paid by Farmers in Australia: Rebasing and General Revision", Quarterly Review of Agricultural Economics, Vol. XXII, No.2, April 1969, p.110.

The real costs could then be used as dependent variables in cost equations. Second, the indices could be used as shift factors in the cost functions, taking on the role of separate explanatory variables in equations in which the cost figures in current prices are used as dependent variables. The first approach has the advantages of conserving degrees of freedom and reducing the risk of multicollinearity. However, in this study it was decided, for the reasons discussed below, to adopt the second approach.

By treating the indices as separate explanatory variables, quantitative estimates of the effects of prices on farm costs can be obtained, along with the standard errors of these estimates. Thus the effects of inflation on farm income may be studied. Secondly, as pointed out above, it is desired to arrive at a model which explains farm income as the residual between gross farm revenues and farm costs. If real farm income is defined as farm income at current prices, deflated by the Consumer Price Index or the implicit G.N.P. price deflator in the A.N.A., then the residual between real farm revenues and real farm costs will not be the same as real farm income thus defined. This is because different price indices are used as deflators for costs, revenues and income. In the section below on simulated disturbances to the farm sector, the model presented in this study is linked with an econometric model of the Australian economy in which farm income, deflated by the implicit G.N.P. price deflator in the A.N.A., is used as a pre-determined variable. Thus it is necessary to first explain farm income at current prices and therefore costs must also be explained at current prices.

MARKETING COSTS

The A.N.A. estimates of marketing costs refer to the costs of freight outwards, bags, sacks, cases and other containers and costs charged to farmers by marketing authorities, brokers, etc., for the actual service of marketing. Apart from variations due to price, these costs would be expected to vary directly with the actual quantity of output produced rather than the number of acres sown or the number of sheep shorn. An estimate of the quantity of farm output was obtained by valuing for each year the quantity of output for each commodity or group of commodities which are covered above by a supply function at average 1960-61 to 1962-63 prices. The prices used were the unit gross values published by C.B.C.S. in the Value of Production Bulletin.

It is recognised that this estimate is an understatement of the quantum of farm output due to the fact that some minor commodity groups are not covered by supply functions. However, this estimate is preferred to the total because it enables a direct link from the supply functions to the equation for marketing costs. Furthermore, for the three years 1960-61 to 1962-63, the items covered by supply functions account for 96.5 per cent of the total gross value of all rural production, thus the items omitted from the estimate of farm output are insignificant.

No other factors apart from the quantum of output and the index of prices paid for marketing expenses were thought to influence marketing costs and so a regression was run using the current year's value of these variables as explanators and with the adjusted A.N.A.

figures for marketing costs as dependent variable. The use of quantum of output as an explanator here when it is itself explained elsewhere in the model does not lead to bias provided the error terms in the supply functions are independent of the error term in the cost equation.[4]

The results of the regression are as follows:

$$MC_t = -178.8 + \underset{(0.01)}{0.12^{**}} QFM_t + \underset{(0.27)}{1.65^{**}} Pmc_t \quad \ldots\ldots\ldots\ (i)$$

$$R^2 = 0.98$$

$$D\text{-}W = 1.23$$

where MC_t = marketing costs in year t,

QFM_t = estimated quantum of farm output in year t,

Pmc_t = B.A.E. index of prices paid for marketing expenses in year t, base average of three years 1960-61 to 1962-63 = 100

The coefficients in the above equation have the expected sign and are highly significant. The degree of explanation is high but the D-W statistic is indicative of positive autocorrelation using the Theil-Nagar test. The Hildreth-Lu procedure was applied to the data in exactly the same fashion as it was above for supply equations that were characterised by autocorrelated errors. The sum of squared residuals reached a minimum for a value of ρ of 0.65. The resulting equation in terms of the original variables was as follows:

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4 See Koopmans, T.C., "When Is An Equation System Complete for Statistical Purposes?" pp.402-406 in Statistical Inference in Dynamic Economic Models, Cowles Commission Monograph No.10, John Wiley and Sons, New York, 1950.

$$MC_t = -185.5 + \underset{(0.01)}{0.10^{**}} QFM + \underset{(0.62)}{2.27^{**}} Pmc_t \quad \ldots\ldots \text{(ii)}$$

$$R^2 = 0.98$$

$$D\text{-}W = 1.62$$

This equation has highly significant coefficients of the anticipated sign, high R^2 and the D-W statistic is now in the non-rejection region of the hypothesis of zero autocorrelation. It is interesting to note that the coefficient on the price index in the non-autocorrelated equation is some 38 per cent greater than in the original equation. The coefficients in the non-autocorrelated equation suggest that at average levels of the variables, a one per cent rise in the prices of marketing items and services results in a 0.7 per cent rise in total marketing costs while a one per cent rise in farm output results in a 0.9 per cent rise in marketing costs.

SEED AND FODDER COSTS

The A.N.A. estimates of seed costs are based on acreages sown using a "fixed sowing rate per acre."[5] Thus the total area cropped might be expected to be a good explanator of the seed part of seed and fodder costs. However, one qualification needs to be made to this. The area under fruit, including vineyards, in any year does not involve any planting of seed and therefore it was excluded from the explanatory variable.

5. Quotation from private correspondence with the Commonwealth Statistician on the subject of farm costs.

Fodder costs refer to actual estimates made by the Statistician of the quantity used of hay, ensilage, green fodder and other stock fodder. Other things equal, fodder costs would be expected to vary with total livestock numbers. Thus the livestock numbers index, which was calculated above in developing a supply model for hay production, was adopted here with slight modification. In the hay supply model, the index was calculated for the beginnings of years on the assumption that farmers' hay production decisions would be based on animals on hand at the beginning of the year. However, fodder costs are likely to be influenced by what happens to livestock numbers during the course of the year. Thus, by simple interpolation, the livestock numbers index was shifted forward to the middle of the year to give an index of average livestock numbers for the year. There is a sense in which this index is related to the dependent variables in the livestock supply functions above. However, as pointed out in the marketing costs section, it can properly be regarded as pre-determined in a cost equation provided the errors in the supply function are independent of the the errors in the cost equation.

In addition to livestock numbers, the stocks of fodder on hand might be expected to influence the costs of fodder. Thus the greater are stocks on hand at the beginning of the year, the more fodder is the farmer likely to use during the year and the greater will be the Statistician's estimate of costs of fodder. Unfortunately, the only fodder items for which data are available on stocks on hand are hay and ensilage. The items "green fodder" and "other stock fodder" in the production figures are fairly minor and in any case the Statistician values the total production of these items in any year in his cost figures. Thus the stocks of hay and ensilage on hand at the beginning of the year were used to represent the stocks of fodder.

Weather conditions in the current year would be expected to have an influence on fodder costs. Drought (reflected by a high value of DMI_t) would be expected to make fodder in short supply thereby increasing its price. The price effect will be reflected in the B.A.E. price index for seed and fodder. Whether or not drought causes increased fodder costs depends on whether stocks are adequate to provide for increased fodder usage in the light of reduced production due to the drought. There is some evidence to suggest that it may be. In Table 12 below the values of DMI_t are listed alongside estimates of the quantity of hay used. These estimates are obtained by defining hay used as being equal to total production minus net increase in stocks during the year. As such they ignore small amounts which are imported, exported and used in factories etc. These amounts are taken into account by the Commonwealth Statistician in his estimates of seed and fodder costs.

As can be seen from Table 12, 1953-54, 1955-56, 1957-58, 1965-66 and 1967-68 were years in which both the use of hay and the drought index rose sharply. However, there were also some years in which the opposite effect is seen. In 1950-51 the drought index rose while hay use declined and in 1961-62, the drought index fell yet hay usage increased. Overall, the correlation between the two was small and negative ($r = -0.02$), however this is no indication of how DMI_t will perform in a multiple regression to explain fodder costs.

TABLE 12

Estimated Quantity of Hay Used and Drought Index

Year	Quantity of Hay Used ('000 tons)	DMI_t
1946-47	2,541.1	119.24
1947-48	2,251.6	96.19
1948-49	2,608.5	97.00
1949-50	2,403.2	72.47
1950-51	2,266.5	147.92
1951-52	2,233.4	127.58
1952-53	2,304.9	67.16
1953-54	2,749.0	90.80
1954-55	2,647.2	76.05
1955-56	3,038.0	84.14
1956-57	2,928.9	102.61
1957-58	3,849.5	132.15
1958-59	2,846.8	84.67
1959-60	4,193.3	93.76
1960-61	3,699.8	95.88
1961-62	4,516.3	70.29
1962-63	4,553.7	98.02
1963-64	4,551.1	75.49
1964-65	4,320.9	74.86
1965-66	5,324.2	182.86
1966-67	5,135.5	71.68
1967-68	5,938.2	88.28
1968-69	4,356.1	67.31

Current weather conditions should not influence seed costs except to the extent that less acres are sown either because (a) the drought was anticipated or (b) the drought was already being felt at planting time. Either way, the effect on seed costs is via acreage and will therefore already be accounted for in the acreage variable. Finally, the B.A.E. Index of Prices paid for seed and fodder was included giving a regression equation of the following form:

$$SFC_t = A + B_1 AC_t + B_2 MLVSK_t + B_3 FSTK_t + B_4 Psf_t + B_5 DMI_t$$

where

SFC_t = seed and fodder costs in year t,

AC_t = area under all crops excluding fruit in year t,

$MLVSK_t$ = livestock index centered at the middle of year t,

$FSTK_t$ = stocks of hay and ensilage at the beginning of year t,

Psf_t = B.A.E. index of prices paid for seed and fodder in year t,

DMI_t = drought mortality index for year t.

The estimated regression coefficients of this equation were as follows:

$$SFC_t = -179.4 + \underset{(1.1)}{6.2^{**}} AC_t + \underset{(1.3)}{0.06} MLVSK_t + \underset{(0.004)}{0.01^{*}} FSTK_t + \underset{(0.14)}{0.26} DMI_t + \underset{(0.4)}{2.01^{**}} Psf_t \quad \ldots\ldots\ldots\ldots \text{(iii)}$$

$$R^2 = 0.96$$

$$D\text{-}W = 1.14$$

All coefficients are of the anticipated positive sign, the coefficient on DMI_t (which is significant at the ten per cent level though not at the five per cent level) confirms earlier suspicions about the effect of this variable on seed and fodder costs. The equation, as estimated, suffers from two major weaknesses. First, the D-W statistic is indicative of positively autocorrelated errors. Second, the correlation matrix presented below shows simple correlation between many of the variables to be high. Both of these effects may be causing the lack of statistical significance on $MLVSK_t$ and DMI_t. That the coefficient

TABLE 13

Correlation Matrix for Variables in Seed and Fodder Cost Equation.

Variable	SFC_t	AC_t	$MLVSK_t$	$FSTK_t$	DMI_t	Psf_t
SFC_t	1.00	0.90	0.94	0.78	-0.00006	0.83
AC_t		1.00	0.87	0.64	-0.20	0.60
$MLVSK_t$			1.00	0.81	-0.10	0.78
$FSTK_t$				1.00	0.02	0.56
DMI_t					1.00	0.05
Psf_t						1.00

on DMI_t even achieves significance at ten per cent is somewhat surprising in view of its almost zero simple correlation coefficient with the dependent variable. However, its partial correlation coefficient is positive at 0.44.

Before applying the Hildreth-Lu procedure to this model, some variants of the specification were experimented with by omitting variables. It was hypothesised that at the very minimum AC_t, $MLVSK_t$ and Psf_t should remain in the specification despite the correlation between AC_t and $MLVSK_t$. When the regression was run using these three only as explanatory variables, the coefficients on all of them were of the expected sign but the coefficient on $MLVSK_t$ was not statistically significant at five per cent. The other two were both significant at one per cent. The D-W statistic was indicative of autocorrelation, using the Theil-Nagar test, at five per cent significance but not at one per cent, the critical values being 1.66 and 1.40 respectively, the value here being 1.53. This means that the probability of getting a sample D-W as small as the one obtained here from a population in which the errors are truly non-autocorrelated is greater than one per cent but less than five per cent.

Thus the estimates are on the margin of acceptability. However, when DMI_t was added to the specification, the same result was obtained for the D-W statistic and the coefficient on DMI_t was significant at ten per cent. It was decided to apply the Hildreth-Lu procedure to both specifications in an attempt to remove any nagging doubts that might remain concerning autocorrelation. For the model with DMI_t excluded, the sum of squared residuals did not reach a minimum in the acceptable range of the autoregressive coefficient (ρ). This is sometimes attributable to mis-specification. For the model with the three basic explanators plus DMI_t, the minimum sum of squared residuals occurred when $\rho = 0.20$. In terms of the original variables, the results for this model are as follows:

$$SFC_t = -3.2 + \underset{(1.5)}{4.6^{**}} AC_t + \underset{(1.3)}{2.6} MLVSK_t + \underset{(0.62)}{1.86^{**}} Psf_t + \underset{(0.16)}{0.26} DMI_t \quad \ldots \text{(iv)}$$

$$R^2 = 0.94$$

$$\text{D-W} = 1.74$$

The D-W statistic from this equation is also within the one to five per cent range, the critical values being 1.54 and 1.81 respectively. However, the value here is much closer to the five per cent critical value than was the case before addition of DMI_t to the specification and before application of the Hildreth-Lu procedure. Since the Theil-Nagar test involves a number of approximations, it was decided that the small difference from the five per cent level here could be tolerated. Thus the above equation was adopted for explaining seed and fodder costs. It should be noted that the coefficient on both $MLVSK_t$ and DMI_t are significant only at ten per cent. For $MLVSK_t$, this result is attributable to the inter-correlation between $MLVSK_t$ and AC_t (see Table 13 above). The low significance of the coefficient on DMI_t, since it cannot be attributable to multicollinearity, indicates that the true effect of DMI_t on seed and fodder costs may be zero. However, zero is not necessarily the best estimate of its coefficient, since the equation as a whole performs better with it included in the specification.

Depreciation

As pointed out above, the A.N.A. figure for depreciation is that which is allowable for tax purposes. Glau[6] and Gruen[7] have outlined the special tax concessions for farmers and their effects in overstating the "real" depreciation costs of farmers. However, as has also been pointed out above, the aim here is to develop a model to explain the Statistician's estimates of farm income. Thus rather than use the

6. Glau, T.E., "The Cost-Price Squeeze on Australian Farm Income", Australian Journal of Agricultural Economics, Vol.15, No.1, April 1971, pp.14-1
7. Gruen, F.H., "An Estimate of Depreciation of Farm Machinery and Structure Based on Historical Cost", Australian Journal of Agricultural Economics,

tax concession provisions to "correct" the Statistician's figures, they must be used here to explain those figures. The essential feature of the provisions is the allowance of straight line depreciation at a rate of 20 per cent per year for five years which is clearly less than the life span of most depreciable items. In addition, for the years 1949-50 and 1950-51, an initial allowance of an extra 20 per cent was allowable in the first year making it possible for the farmer to write off 120 per cent of the cost of the asset over five years.

If detailed data on the value and age of the farm capital stock were available, the task of Glau and Gruen, and of this study, would have been considerably eased. A reasonable amount of information on stocks and purchases of farm machinery and tractors is available from the Rural Industries Bulletin, however, no information is available on farm improvements such as fences, watering points, buildings, etc. which qualify for depreciation allowances. The approach adopted by Glau and by Gruen was to use the A.N.A. figure for gross fixed capital expenditure by the farm sector as an estimate of the additions to the stock of capital each year.

If the figures for gross fixed capital expenditure are taken together with the taxation provisions, the following points may be made. First, the fourth year after expenditure occurs is the last year for which it can be used for allowable depreciation, assuming the farmer starts writing off the asset in the year of purchase. Second, assuming all of the capital expenditure qualifies for the accelerated depreciation rate, 20 per cent of the expenditure in t-4 is allowable as a deduction for taxation in t. Thus a "depreciation base" may be defined as the sum of 20 per cent of each year's capital expenditure from year t to year t-4.

In Table 14 below, both the depreciation cost and the depreciation base are shown, adjusted to a rural year basis.

Since the A.N.A. figures on capital expenditure are only available back to 1948-49, the earliest year for which the depreciation base could be calculated was 1952-53. The base is consistently higher than the actual depreciation figures. This is most likely a reflection of the fact that the A.N.A. figure includes purchases of secondhand plant and equipment, estimated by Gruen[8] to be 15 per cent of the total. In addition, the capital expenditure figure may include some items which are not subject to the special taxation provisions.

Nevertheless, it was felt that the base should be a good explanator of depreciation costs. Since both the base and the depreciation costs are in current prices it was felt that it was not necessary to include an index of depreciation costs as an explanator even though it seemed that a relevant index could be calculated from the material supplied by the B.A.E. on prices paid (see Table 11 above).

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8. Gruen, F.H., "An Estimate of Depreciation of Farm Machinery....", op.cit., p.182.

TABLE 14

Depreciation Costs and Calculated Depreciation Base, Adjusted to a Rural Year Basis.

Year	Depreciation Costs $m.	Depreciation Base $m.
1952-53	152.5	224.2
1953-54	192.0	258.8
1954-55	223.0	283.2
1955-56	243.5	292.8
1956-57	247.0	296.0
1957-58	267.2	309.0
1958-59	284.8	312.4
1959-60	292.5	321.2
1960-61	302.0	334.4
1961-62	309.8	340.2
1962-63	325.5	354.8
1963-64	362.2	394.8
1964-65	378.8	428.6
1965-66	391.2	448.6
1966-67	428.0	491.4
1967-68	448.2	520.6
1968-69	456.2	533.4

Source: Calculated from C.B.C.S., "Australian National Accounts", various issues.

The results of the regression of the depreciation costs on the base were as follows:

$$DC_t = -28.2 + \underset{(0.05)}{0.94^{**}} DB_t \quad \ldots\ldots\ldots\ldots \quad (v)$$

$$R^2 = 0.96$$

$$D\text{-}W = 0.21$$

where DC_t = depreciation costs in year t,

DB_t = calculated depreciation base for year t.

The regression yields good explanation with a highly significant coefficient on the depreciation base. However, the D-W statistic is indicative of positive auto-correlation. When the Hildreth-Lu procedure was applied to remove the effects of autocorrelation, the sum of squared residuals did not reach a minimum in the acceptable range for $\rho(-1 \leq \rho \leq +1)$.

It is thought that this may be due to mis-specification. The depreciation base is affected by capital expenditure in the current year. It might be expected that current capital expenditure would be a function of current farm income, amongst other things, and of course current farm income is a function of current depreciation costs. Thus a problem of inter-dependency arises with depreciation depending upon farm income and vice versa. To get around this problem, a function explaining capital expenditure would need to be specified and the coefficients of the system coudl then be estimated using 2SLS. However, it was considered beyond the scope of this study to develop a model of farmers' investment behaviour.

Two options thus appear open with respect to depreciation costs. Either the above equation for depreciation can be accepted, with its auto-correlation, and capital expenditure can be taken as pre-determined, or depreciation itself can be taken as pre-determined. On balance it was felt that the latter choice was preferable for two reasons. First, the equation for depreciation is of limited predictive power, requiring some assumptions to be made about the size of capital expenditure and second, depreciation costs at any point in time are influenced by government policy on both the rate of depreciation and on the nature of the items subject to this rate. Government policy is something which clearly must be taken as exogenously determined.

Other Farm Costs n.e.i.

The large residual item of farm costs covers such costs as wages, interest, rent, fertiliser, fuel, power, maintenance contracts and indirect taxes. For the cropping industries, costs such as wages, fertiliser, rent and fuel are more likely to be a function of area cropped than the volume of output that is produced. Thus the more acres that are cultivated, the longer is labour time devoted to sowing and harvesting, the more fertiliser and fuel is likely to be used and to the extent that the extra area is newly rented, the higher will be total rent costs. Accordingly, the total area of all crops was used as one explanatory variable in a regression equation to explain other costs, n.e.i.

For the livestock industries, a general relationship might be expected between livestock numbers and other costs. Thus the more animals there are on hand the greater the expenses of tending them. This relationship is modified by the fact that labour costs and contract costs would tend to vary with the number of sheep actually shorn and the number of animals marketed. However, both of these are highly correlated with livestock numbers and thus it was decided to use as an explanator the centred livestock numbers index that was developed above in the section on seed and fodder costs. As was pointed out in that section, the total area cropped and the centred livestock numbers index can both be regarded as pre-determined with respect to a cost function, provided it is assumed that the error terms in the supply functions are independent of those in the cost function.

The Reserve Bank of Australia publishes estimates of the total of rural debt to institutional lenders.[9] Although some economists believe the level of rural debt from private sources may be as great as that from institutions,[10] the A.N.A. cost figures are based on institutional debt only and thus it was felt that the institutional debt figure would be a good explanator for the interest component of the conglomerate other farm costs n.e.i.

Finally, an index of prices paid relevant to this conglomerate was calculated from B.A.E. material using the items as shown in Table 11 above. The results of the regression of other costs n.e.i. on the four explanators was as follows:

$$OFC_t = -365.7 + \underset{(3.8)}{8.5^{*}}TAC_t + \underset{(2.2)}{1.5}MLVSK_t + \underset{(0.1)}{0.2}FD_t + \underset{(1.2)}{6.8^{**}}PI_t \quad \ldots\ldots (vi)$$

$$R^2 = 0.99$$

$$D\text{-}W = 0.96$$

where OFC_t = other farm costs, n.e.i. in year t,

TAC_t = total area cropped in year t,

$MLVSK_t$ = livestock numbers index centered in the middle of year t,

FD_t = total rural debt to institutional lenders in year t,

PI_t = calculated index of prices paid for other farm costs n.e.i. in year t.

9. See any recent issue of Reserve Bank of Australia, Statistical Bulletin - Financial Supplement.

10. See Glau, T.E., op.cit., p.5.

All coefficients in this equation are of the expected sign with the coefficients on area cropped and the price index being statistically significant at five per cent or better. The degree of explanation is high but the D-W statistic is indicative of positive autocorrelation. This may be the cause of the lack of significance of the coefficients on the livestock numbers index and on rural debt. However, an equally likely cause of this lack of significance is the rampant inter-correlation between the explanatory variables which is evidenced by the correlation matrix given in Table 15 below.

TABLE 15

Correlation Matrix for Regression Equation to Explain Other Farm Costs n.e.i.

Variable	OFC_t	TAC_t	$MLVSK_t$	FD_t	PI_t
OFC_t	1.00	0.93	0.95	0.98	0.96
TAC_t		1.00	0.87	0.96	0.82
$MLVSK_t$			1.00	0.93	0.94
FD_t				1.00	0.91
PI_t					1.00

Despite this high degree of inter-correlation, it was hypothesised that all four explanatory variables should remain in the specification. The Hildreth-Lu procedure was applied to the data in an attempt to overcome the autocorrelation, however, the sum of squared residuals did not reach a minimum in the acceptable range for the autoregressive coefficient, $\rho(-1 \leq \rho \leq +1)$. This may again be attributable to mis-specification in that the current level of farm debt may itself be a function of farm income which is a function of farm costs n.e.i. Thus an inter-dependent system would need to be specified, with an equation explaining farm debt. However, this was considered beyond the scope of this study and so it was decided to continue to regard farm debt as pre-determined.

Another explanation for the failure of the Hildreth-Lu procedure here is that the autoregressive structure may be more complicated than a first order Markov. As a test for this, Marceau[11] proceeded by regressing the estimated residuals on their first, second, third, etc. period lagged values. It was decided to test for up to a third order autoregressive scheme by the following regression equation:

$$u_t = \rho_1 u_{t-1} + \rho_2 u_{t-2} + \rho_3 u_{t-3} + \varepsilon_t$$

where u_t refers to estimated residuals. When this was applied neither the second nor third order coefficients were statistically significant at five per cent suggesting that the assumption of a first order scheme is justified.

In an attempt to break this autocorrelation deadlock, various experimental specifications were tried. In particular, the drought mortality index (DMI_t) and the estimated quantum of farm output (QFM_t) were added in various combinations with the four variables in equation (vi) above. In every case, the D-W statistic was indicative of autocorrelation and in every case when the Hildreth-Lu procedure was applied,

11. Marceau, I.W., op.cit., p.44.

the sum of squared residuals failed to reach a minimum in the acceptable range for ρ.

Thus it seems likely that the mis-specification of farm debt may well be the cause of the trouble. Since this is considered to be out of scope, it was decided to accept equation (vi) given that the standard errors of the coefficients are influenced by both auto-correlation and multicollinearity.

Conclusions.

In concluding this section on farm costs it must be said that the difficulties in developing farm cost equations on a national basis could be lessened were a more detailed breakdown of costs available. Nevertheless, it is believed that this section has developed some useful equations for forecasting movements in the various cost aggregates, particularly those movements which are conditional upon movements in production aggregates such as acreage, livestock numbers and slaughterings and upon drought conditions.

CHAPTER 9

SUMMARY OF THE MODEL

In this section the preferred equations for each of the supply functions and cost functions discussed above are brought together. The value of the estimated coefficients only are given here, no standard errors, R^2 or D-W statistics are presented. In addition to the supply and cost functions, various identities are presented here which tie the two areas together to arrive at farm income. This step is necessary before proceeding to the simulation section below. A list of the variables used in the regression equations together with the data is to be found in the Appendix at the end of this study. The concepts used in the identities are spelt out fully in this section. All endogenous variables are indicated by a single dagger (†), all other variables are taken as predetermined or exogenous to the system.

SUPPLY SECTION

Wheat Supply

$$WT\overset{\dagger}{A}_t = -44{,}225 + 591\ MTW_{t-1} + 36E(Pwt/Pwl)_t$$

Gross value of wheat production = $WT\overset{\dagger}{A}_t$ x wheat yield per acre x average price of wheat.

Coarse Grains Supply

$CGA^{\dagger}_t = 174.5 + 15.1\ E(Pog/Pwt)_t + 224TIME$

Gross value of coarse grains production = $CGA^{\dagger}_t$ x average coarse grains yield per acre x average coarse grains price.

Sugar Supply

$SAC^{\dagger}_t = 210.2 + 0.22\ SX_{t-1}$

Gross value of sugar production = $SAC^{\dagger}_t$ x sugar yield per acre of cane crushed x average price of sugar.

Fruit Supply

$FQP^{\ddagger}_t = -59 + 4.6\ FIP_{t-1} + 0.2\ PF_{t-5}$

Gross value of fruit production = $FQP^{\ddagger}_t$ x current period price index for fruit.

Vegetable Supply

$VQP^{\ddagger}_t = 30.9 + 0.13VPM_{t-1} + 0.13\ VFU_{t-1}$

Gross value of vegetable production = $VQP^{\ddagger}_t$ x current period price index for vegetables.

Hay Supply

$AH^{\ddagger}_t = -7{,}237 + 95.2\ LVSK_t + 4.2\ ALDIS_t - 0.28\ HSTK_t$

Gross value of hay production = $AH^{\ddagger}_t$ x yield of hay per acre x average price of hay.

Wool Supply

$TNF^{\dagger}_t = 176.3 + 1.88\ AP_t - 0.09\ ALDIS_t$

$SLSH^{\dagger}_t = 4.74 + 0.85\ TNF^{\ddagger}_t - 0.09\ DMI_t$

Gross value of wool production $= SLSH^{\dagger}_{t}$ x average fleece weight x average wool price.

Sheep and Lambs for Slaughter - Supply and Demand

$$SLK^{\dagger}_{t} = 37{,}069 + 209\ Psm^{\dagger}_{t} + 282\ TNF^{\dagger}_{t} - 62.1\ DMI_{t} - 55.8\ Pwl_{t}$$

$$Psm^{\dagger}_{t} = 142.7 - 0.007\ SLK^{\dagger}_{t} + 0.14\ YPDH_{t} + 0.25\ MLX_{t}$$

Gross value of sheep and lambs slaughtered $= SLK^{\dagger}_{t}$ x average slaughter price of sheep and lambs.

Cattle and Calves for Slaughter - Supply and Demand

$$NCS^{\dagger}_{t} = 326.08 + 17.4\ Pb^{\dagger}_{t} + 10.5\ ALPB_{t} - 2.9\ ALDI_{t}$$

$$Pb^{\dagger}_{t} = 14.2 - 0.004\ NCS^{\dagger}_{t} + 0.1\ YPDH_{t} + 0.01\ BX_{t}$$

Gross value of cattle and calves slaughtered $= NCS^{\dagger}_{t}$ x average slaughter price of cattle and calves.

Pigs - Supply and Demand

$$NSOW^{\dagger}_{t} = 5.86 + 0.56\ (Pp/Pg)_{t-1} + 0.007\ TGA_{t-1}$$

$$NPS^{\dagger}_{t} = 1{,}827 + 11.1\ RPP^{\dagger}_{t} + 13.8\ NSOW^{\dagger}_{t}$$

Gross value of pigs slaughtered $= NPS^{\dagger}_{t}$ x average slaughter price of pigs.

Dairy Products Supply

$$WMP^{\dagger}_{t} = 935.8 - 0.7DMI_{t} + 5.8\ E(Pd)_{t} + 0.2\ TPN_{t-1}$$

Gross value of dairy production $= WMP^{\dagger}_{t}$ x average price of dairy products.

Poultry Products Supply

$$QCH_t^{\dagger} = 44.93\ (1.065)^{TIME}$$

Gross value of poultry production = $QCH_t^{\dagger}$ x current period price index for poultry products.

COST SECTION

Marketing Costs

$$MC_t^{\dagger} = 185.5 + 0.10\ QFM_t + 2.27\ Pmc_t$$

Seed and Fodder Costs

$$SFC_t^{\dagger} = 312 + 4.6AC_t + 2.6\ MLVSK_t + 1.86\ Psf_t + 0.26\ DMI_t$$

Depreciation Costs are taken as pre-determined.

Other Farm Costs n.e.i.

$$OFC_t^{\dagger} = 365.7 + 8.5\ TAC_t + 1.5\ MLVSK_t + 0.2FD_t + 6.8\ PI_t$$

Total Farm Costs = $MC_t^{\dagger} + SFC_t^{\dagger} + OFC_t^{\dagger}$ + depreciation costs

FARM INCOME IDENTITIES

Gross value of Rural Production = Gross Value of wheat production + Gross value of coarse grains production + Gross value of sugar production + Gross value of fruit production + Gross value of vegetable production + Gross value of hay production + gross value of wool production + gross value of sheep and lambs slaughtered + gross value of cattle and calves slaughtered + gross value of pigs slaughtered + gross value of dairy production + gross value of poultry products + gross value of other rural production not elsewhere specified.

Farm Income = gross value of rural production - Total Farm Costs.

CHAPTER 10

SIMULATION.

Introduction

In this section it is proposed to utilise the results of previous sections to study the effects of simulating certain changes in the rural sector. The econometric model of the Australian farm sector that has been developed in this study has emphasised the explanation of farm income. In particular, attention has been paid to paving the way for studying the effect on farm income of supply responses to various stimuli. The emphasis on farm income is to enable a link to be established between the farm sector and the rest of the economy. In almost every econometric model of the Australian economy that has been developed, farm income has been taken as a pre-determined variable. It is now proposed to link the econometric model of the farm sector developed here with J.A. Zerby's model of the Australian economy using farm income as the point of tangency between the two models. Zerby's model was preferred to the Reserve Bank and Treasury models, not because it was thought to be superior but because it was an annual model, like the model of the farm sector developed here, while the other two are quarterly models. It was preferred to the Nevill and Kmenta models because it is more comprehensive and more up to date than those two models.

Zerby's model is one of interdependence with endogenous variables appearing in more than one equation. The model contains eleven equations and three identities explaining a total of fourteen endogenous variables using twenty-five predetermined variables. Zerby provides both OLS, 2SLS and three stage least squares (3SLS) estimates of the equation coefficients. In matrix notation his model is of the form:

$$AY + BZ = Y$$

where A is a 14 x 14 matrix of coefficients on endogenous variables,

Y is a 14 x N matrix of endogenous variables with N being the number of observations,

B is a 14 x 25 matrix of coefficients on pre-determined variables,

Z is a 25 x N matrix of pre-determined variables.

The coefficients of the A and B matrix are presented in Zerby's study. It is a simple matter to rearrange his model to arrive at the reduced form where all endogenous variables are expressed as functions of the pre-determined variables and nothing else, thus,

$$Y = (I - A)^{-1}BZ$$

which can be written as $Y = CZ$

where C is a 14 x 25 matrix of reduced form coefficients. The coefficients of the C matrix were computed for each of Zerby's three estimating procedures. Of particular interest is the column of the

C matrix which shows the effect on each of the endogenous variables of a one unit change in farm income.[1] This column for each of the three estimating methods is reproduced in Table 16 below. These coefficients are equivalent to Goldberger's "impact multipliers".[2] They give the immediate effect on the endogenous variables of a one unit change in farm income. They do not take into account the lagged effects which result from lagged values of endogenous variables appearing as explanators in some equations in Zerby's model. These effects are reflected in Goldberger's "delay multipliers".

TABLE 16

Zerby's Reduced Form Coefficients for the Effects of Farm Income.

Endogenous variable	Estimating Method		
	OLS	2SLS	3SLS
CD	-0.002	0.337	0.320
CN	-0.011	1.094	0.702
ID	-0.120	0.021	-0.019
IF	0.0	0.0	0.0
ΔS	-0.077	-0.139	-0.106
M	-0.008	0.051	0.040
Y	-0.202	1.263	0.858
YN	-0.123	0.804	0.578
YD	0.877	1.804	1.578
E	-0.133	1.452	1.003
YC	-0.012	0.124	0.867
A	0.163	0.360	0.488
R2	0.351	0.631	0.539
R10	0.123	0.221	0.089

where :

CD = expenditure on consumer durables,

CN = expenditure on consumer non-durables,

ID = expenditure on construction of private dwellings,

1. Zerby does not specifically give the units in his study but the indication from p.162 is that they are in \$m.
2. Goldberger, A.S., op.cit., pp.374-375.
3. Ibid.

IF = gross private fixed investment expenditure,
ΔS = change in non-farm stocks,
M = current imports,
Y = gross national product,
YN = non-farm personal income,
YD = total personal disposable income,
E = total domestic expenditures,
YC = company income,
A = liquid assets (not clearly defined by Zerby),
R2 = short term rate of interest,
R10 = long term rate of interest,

all money values being deflated by the implicit G.N.P. price deflator in the Australian National Accounts.

There are a number of features of Table 16 worth noting. First, the negative sign on many of the OLS estimates is contrary to expectations and is likely due to OLS bias in an inter-dependent system. The 3SLS multipliers have signs which generally agree with a priori expectations. A notable exception is the negative sign alongside ID, suggesting a negative effect on dwelling investment from farm income. This is traceable in Zerby's model to a negative coefficient on farm income in the equation to explain dwelling investment.[4]

The coefficient on ΔS suggests that increases in farm income cause non-farm stocks to be run down. This is so regardless of the estimating procedure and is possibly explicable by farmers' consumption expenditure not being anticipated by businessmen. The zero coefficients alongside IF in all three cases suggest that the net effect of farm income on gross private fixed capital expenditure is zero which is a surprising result in the light of the widely held belief that farmers

4. Zerby, J.A., op.cit., p.163.

tend to finance investment expenditure out of increases in income. However, it should be borne in mind that these zero coefficients represent the impact effect only, and it is likely that responses of farm investment to farm income changes would not show up in national data until after a one year lag.

A further unusual feature which applies to all three estimating procedures relates to the multiplier on Personal Disposable Income (YD). In all cases the multiplier on YD is greater than the multiplier on G.N.P. (Y). Even allowing for changes in farm income to have a greater than unity effect on YD, it seems inconceivable that the effect on YD could be larger than the effect on G.N.P. All personal incomes which are affected by changes in farm income are subject to taxation leakages before they affect personal disposable incomes. In Zerby's model farm income and personal taxation both appear in an identity for personal disposable income.[5] Unfortunately Zerby takes taxation as autonomous, thus a change in farm income has no effect on personal taxation in the model. The change in YD will thus be the full change in farm income, plus the change in personal income in the non-farm sector which arises as a result of farmers' expenditure responding to their changed income.

The negative signs on most of the OLS coefficients led to the decision to discard them for purposes of grafting the farm sector model onto the national model. For the 3SLS estimates, the multiplier on Gross National Product at 0.858 was smaller than expected. Since farm income is itself a component of G.N.P., the impact effect of a

5. Zerby, J.A., op.cit., p.168.

unit change in farm income, should it seems, result in at least a unit change in G.N.P. in the same direction. In other words, the impact multiplier on G.N.P. should at least be unity. Since it is proposed here to look at the effects on G.N.P. of various rural phenomena, it was decided to discard the 3SLS multiplier as being of dubious reliability.

The 2SLS multipliers have generally "correct" signs and the multiplier on G.N.P. at 1.263 was in the range which was to be expected. On the basis of this *a priori* reasoning it was decided to use the 2SLS multiplier of 1.263 to link the model of the rural sector to the model of the whole economy and in particular to study the effects on G.N.P. of various forces operating on farm income.

Finally, as has been pointed out above, farm income appears to substantially affect personal disposable income (YD). It will be recalled that in the livestock industries section below, personal disposable income was treated as a pre-determined shift factor in demand functions. It would seem that it should not be treated as such if it affects farm income which in turn affects personal disposable income, i.e. the grafting of the farm sector model to Zerby's model would seem to require defining personal dispcsable income, i.e. the grafting of the farm sector model to Zerby's model would seem to require defining personal disposable income and farm income as endogenous variables in one big combined model. The coefficients of each would then have to be re-estimated with the new specification, presumably using 2SLS.

However, this task was felt to be beyond the scope of this study. It was felt that the two models could properly be regarded as separate with separate specifications. Few variables are ever likely to be 100 per cent pre-determined but in specifying a model, a line has to be drawn somewhere between endogenous and pre-determined variables. It was felt to be entirely reasonable to draw the line at personal disposable income for the farm sector model. Thus the model can be used to analyse (or synthesise) movements in farm income which can then be taken as exogenous for the economy as a whole.

In the sections that follow four simulations are studied, namely a fall in wheat prices, a drought, general inflation and a fall in wool prices. The farm sector model developed in this study is used to calculate the movements in various revenue and cost items and in farm income resulting from these simulations. For purposes of comparison, the "status quo" is taken to be the average of each series for the last five years of the sample period. The simulations are then studied in terms of changes from this status quo with all else held constant. The changes in farm income are then applied to the 2SLS reduced form coefficient alongside Gross National Product. It should be noted that this procedure only quantifies the impact effect on G.N.P. of the various immediate and delayed effects of changes within the farm sector. The reason for this is that the calculations become very complicated with lagged effects in the farm sector overlapping lagged effects on G.N.P. G.N.P. was isolated for consideration because of its obvious importance and because little confidence was held in the accuracy of many of the other reduced form coefficients.

The Effect of a Fall in Wheat Prices.

It was arbitrarily decided to hypothesise a fall in the wheat price of ten per cent from its status quo level, attributable say to a glut on world markets.

There is no special significance attached to this figure. The first supply responses to the change in wheat price do not occur until the year following the fall, thus the immediate effect on gross value of wheat production and on farm income is due entirely to the fall in price. This amounted to \$55.4m. at average 1966-67 prices using the status quo level of the implicit G.N.P. price deflator in the A.N.A. The resultant fall in G.N.P.[6] is \$70.0m., which is only 0.32 per cent of status quo G.N.P.

In the year after the fall in wheat price, the following responses occur: wheat acreage via the wheat price, coarse grains acreage via the wheat price, pig slaughterings via grain prices. As a result of these production changes, marketing costs, seed and fodder costs and other farm costs n.e.i. are all affected.[7] Table 17 summarises the effect of the supply responses on each revenue item, on costs, on farm income and on G.N.P.

The changes shown in Table 17 are changes which occur in year t+1 as a result of a ten per cent fall in wheat prices in year t. For the farm sector, the effects shown are the various response effects which are calculated from the functional relationships developed earlier

6. All farm income and G.N.P. values will henceforth be given in 1966-67 prices.

7. In calculating the effects of this and other simulations, any revenue or cost effect which was less than \$0.1m. was treated as being insignificant.

TABLE 17

Changes in Main Aggregates One Year After a Ten Per Cent Fall in Wheat Prices

Revenue	$m.	$m.
Gross value of production of wheat	-8.5	
Gross value of production of coarse grains	+3.7	
Gross value of pigs slaughtered	-0.2	
Total		-5.0
Costs		
Marketing costs	-0.2	
Seed and fodder costs	-0.8	
Other farm costs n.e.i.	-1.5	
Total		-2.5
Farm Income		-2.5
G.N.P.		-3.2

in this study. The G.N.P. change is the impact effect of the $2.5m. fall in farm income.

Of note from Table 17 is the increase in coarse grain revenue as farmers switch from wheat into coarse grains and the reduction in gross value of pigs slaughtered. This latter effect is small but is brought about by the interaction of supply and demand for pigs. The supply curve is shifted outwards as farmers concentrate less on wheat growing and more on pig raising and there is an increase in sow numbers and pig slaughterings. However, the price elasticity of demand for pigs is such at status quo levels of prices and slaughterings that the fall in price necessary to absorb the increase is more than proportionate to the rise in slaughterings. Also of note from Table 17 is the fact that the revenue fall is offset by a fall in costs.

It was decided to allow wheat prices to return to their status quo level after one year. Because of lags in the various supply equations, the status quo level for costs, revenues etc. is not restored until four years after the one year only ten per cent fall in wheat prices. Thus in each year for four years there is an effect on revenues, costs, farm income and G.N.P. These effects can be accumulated over the four years to show the total "response" effects of the fall. They can then be combined with the initial effect to give the total cumulative effect over a five year period. In Table 18 the total response effect on each of revenues, costs, farm income and G.N.P. is shown. The effect on G.N.P. is an accumulation of the impact effect for each year.

A comparison of Tables 17 and 18 shows that the second, third and fourth year effects are minor compared to the first year effects. This is especially true for the effects on G.N.P. where the second, third and fourth year effects only amount to \$0.1m. Also of interest from Table 18 is the fact that the total response effect of the gross value of pig slaughterings is less than the first year response effect. This is due to a reduction in pig slaughterings in the second year due to the fall in total grain acreage (see pigs supply section above). Because of demand conditions, the rise in price is more than proportionate to the fall in slaughterings causing a small rise in gross value of pig slaughterings in the second year.

TABLE 18

Total Response Effects on Main Aggregates of a One Year Ten Per Cent Fall in Wheat Prices.

Revenue	$m.	$m.
Gross Value of production of wheat	-11.8	
Gross value of production of coarse grains	+5.1	
Gross value of pigs slaughtered	-0.1	
Total		-6.8
Costs		
Marketing costs	-0.8	
Seed and fodder costs	-1.1	
Other farm costs n.e.i.	-2.0	
Total		-3.9
Farm Income		-2.9
G.N.P.		-3.7

If the total response effect on G.N.P. is combined with the initial impact, the overall reduction in G.N.P. amounts to $73.7m. over five years, or a little over 0.10 per cent annually. Ninety-five per cent of this effect is the pure impact effect in the year price falls. Thus in conclusion it may be said that the response effects of a fall in wheat prices are fairly minor by comparison with the impact effect in the year of the fall. The larger the fall, the larger will be the impact effect but indications from the above analysis suggest that a ten per cent fall in wheat prices results in only a 0.10 per cent fall in G.N.P. on an annual basis.

The Effects of Drought.

In this section it is proposed to trace the effects of a widespread drought on farm revenues, costs, income and on G.N.P.. Considerable use is made of the drought mortality index (DMI) discussed in Chapter 2. In the widespread and severe drought of 1965-66 in Australia, DMI rose by 22 per cent to its highest level for the sample period. In the same year wheat yields and average coarse grain yields fell by 23 per cent and 19 per cent respectively. In the 1957-58 drought, DMI rose by 57 per cent while the wheat and coarse grain yields fell by 39 per cent and 29 per cent respectively. For the purposes of this study it was decided to simulate a drought which caused DMI to rise from its status quo level by 50 per cent, and which causes a 20 per cent fall in both the wheat and coarse grains yields. In the light of Australia's history, this is a fairly mild drought.

It will be assumed that, apart from wheat and coarse grains, those supply sectors which do not specifically use DMI or some derivative of it as an explanator are unaffected. This leaves wool, wheat, coarse grains, sheep and lambs for slaughter, hay,cattle and calves for slaughter and dairying as affected industries. It is also assumed that the drought does not affect acreages of wheat and coarse grains. This is justifiable by reference to the fact that in the 1957-58 and 1965-66 droughts, the effect on acreages of these grains was no more than a temporary slow down of the rate of growth.

As was done above for a fall in wheat prices, the effects of drought are looked at in terms of their immediate or impact effect, their first year response effect and their total response effect. Table 19 below summarises the immediate or impact effect of the drought. The rise in the gross value of sheep and lambs slaughtered of \$2.8m. is due to the elasticity of demand at status quo levels of prices and slaughterings being such that the rise in price was more than proportionate to the fall in slaughterings consequent upon the drought.

It is interesting to note from Table 19 that the crop industries (wheat, coarse grains and hay) were generally more highly affected than the livestock industries in the year of the drought. This is no doubt a reflection of the fact that the immediate effect on crops is generally the only effect while the effect on livestock is felt over a number of years. Also worth noting is that the reduction in marketing costs brought about by reduced farm output is largely offset by the increase in fodder costs.

If it is assumed that the drought lasts for one year only, and conditions thereafter return to status quo, then the various lags in the system can be used to trace the time path of responses to the drought. The status quo returns to most industries in the sixth year after the drought. However, for cattle and calves for slaughter some minor damped oscillations continue up to the eleventh year. As these effects were fairly minor after the sixth year it was decided to ignore them and in Table 20 the one year and cumulative five year response effects of the drought are shown.

It is interesting to note that the gross value of sheep and lambs slaughtered continues to rise because of the low demand elasticity. This is to be contrasted with the change in gross value of cattle and

TABLE 19

Impact Effect of Simulated Drought

Revenue	$m.	$m.
Gross value of wheat production	-111.3	
Gross value of coarse grains production	-27.4	
Gross value of wool production	-18.2	
Gross value of milk production	-8.5	
Gross value of hay production	-16.4	
Gross value of sheep and lambs slaughtered	+2.8	
Total		-178.9
Costs		
Marketing costs	-18.3	
Seed and fodder costs	+12.6	
Other farm costs n.e.i.	-	
Total		-5.7
Farm Income		-173.2
G.N.P.		-218.8

calves slaughtered of-$41.9m. reflecting a higher price elasticity of demand for beef meats compared to sheep meats. Also, after a first year decrease due to reduced livestock numbers, the value of hay production subsequently expands in response to farmers' drought expectations and drought recovery programs resulting in a net increase over the five years.

This is the reason for the five year reduction in seed and fodder costs being less than the first year reduction. After the first year fodder costs continue to be less than status quo values because of reduced livestock numbers but seed costs begin to grow as hay production

TABLE 20

One and Five Year Response Effects of a One Year Simulated Drought

Revenue	$m. One Year	$m. Five Years
Gross value of production of wool	-18.5	-70.1
Gross value of production of hay	-10.3	+16.8
Gross value of sheep and lambs slaughtered	+0.8	+3.0
Gross value of cattle and calves slaughtered	-3.3	-41.9
Total	-31.3	-92.2
Costs		
Marketing costs	-3.6	-11.0
Seed and fodder costs	-17.1	-14.0
Other farm costs n.e.i.	-11.8	-12.0
Total	-32.5	-37.0
Farm Income	+1.2	-55.2
G.N.P.	+1.5	-69.7

increases. For this reason the five year reduction in total costs is not very much greater than the one year reduction.

Also of interest from Table 20 is the fact that the net effect on farm income in the first year is positive. This is mainly achieved through the large savings in fodder costs. It is of note that large losses in revenue from wool and cattle and calves occur after the first year as the effects of the drought on flock and herd size and fertility are progressively felt over time. The total cumulative fall in G.N.P.

is \$288.5m. of which 76 per cent is the impact effect. At an average annual rate of \$57.7m., this fall represents only 0.26 per cent of the status quo value of G.N.P.. While this does not appear to be a very large loss, in terms of unemployment, it may represent a significant increase in the proportion out of work.[8]

The cumulative loss in farm income as a consequence of the drought was \$228.4m. which, on an annual basis, represents 3.9 per cent of the status quo level of farm income. Thus the consequences for industries dependent upon the rural sector may be expected to be quite significant even though the aggregate national effect of the drought may not be.

The Effects of Inflation

In view of the qualitative attention that some rural spokesmen have given to the effects of inflation on agriculture, it was considered to be of interest to attempt to quantify these effects using the model developed in earlier sections. In addition to the obvious effect on costs of rising input prices, there are certain supply response effects where "real" prices are used as explanatory variables. For purposes of the simulation it was decided to arbitrarily assume a rate of inflation of five per cent per annum. This rate has some relevance to recent experiences since the percentage rates of increase of the Consumer Price Index and the B.A.E. Index of prices paid by farmers have varied between 4.1 per cent and 6.6 per cent over the period 1969-70 to 1971-72.

By applying the five per cent rate of inflation to the status quo level of the index of prices paid, new (lower) real prices can be

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8. Zerby's model did not explain unemployment and so the effects on unemployment of the fall in G.N.P. cannot be quantified.

calculated for cattle and calves for slaughter, sheep and lambs for slaughter and dairy products. For wool the effect of price was not able to be specifically quantified in the supply section above. However, as was pointed out in that section, +0.05 would seem to be a reasonable estimate of the price elasticity of supply of sheep numbers shorn, judging from the results of other studies. Thus supply response effects can be calculated for all of wool, cattle and calves, sheep and lambs and dairying. All other sectors do not use real prices as explanators and therefore it is assumed that there are no response effects for those sectors.

If it is assumed that the response of sheep shearings to a lower real wool price is instantaneous (i.e. in the same year), then only dairying has a response effect which extends beyond one year. However, the studies from which the estimated supply elasticity of +0.05 was obtained, specify a one year lag on price. Thus both the wool and dairy effects extend beyond one year. In the year in which a five per cent rate of inflation is introduced to the status quo, there are response effects from cattle and calves for slaughter and sheep and lambs for slaughter as well as there being immediate effects on marketing costs, seed and fodder costs and other farm costs n.e.i.

To obtain the response effects for the two livestock industries, their structural form rather than their reduced form must be used since the real prices are endogenous variables. Thus the new equilibrium resulting from a five per cent fall in the real price is obtained as the result of a series of dampened oscillations. The immediate effect on gross value of production in those industries, on costs, farm income and G.N.P. is summarised in Table 21.

It should be noted that in calculating the effects on farm costs, it was assumed that the price indices in each cost equation were autonomously increased by the five per cent rate of inflation. It can be seen that the increase in other farm costs n.e.i. dominates the reduction in farm income, accounting for 53.6 per cent of it, the two supply response effects in total only accounting for 17 per cent of the fall in farm income. The G.N.P. loss of $91.2m. is only 0.40 per cent of the status quo level. However, it is of interest to observe that such a loss of real G.N.P. can occur because of purely monetary phenomenon, i.e. price inflation.[9]

TABLE 21

Immediate Effects of a Five per cent Rate of Inflation.

Revenue	$m.	$m.
Gross value of cattle and calves slaughtered	-7.2	
Gross value of sheep and lambs slaughtered	-5.1	
Total		-12.3
Costs		
Marketing costs	+11.1	
Seed and fodder costs	+10.1	
Other farm costs n.e.i.	+38.7	
Total		+59.9
Farm Income		-72.2
G.N.P.		-91.2

9. It might be reasonably expected that a five per cent rate of inflation would affect depreciation costs. If depreciation costs are assumed to rise a full five per cent from their status quo level, this means a further fall in farm income of $21.0m. and a fall in G.N.P. of $26.5m. However, this is an upper estimate since depreciation costs are unlikely to rise by the full five per cent rate of inflation.

If the five per cent rate of inflation persists for more than one year, the effects in subsequent years upon the various revenue and cost items in Table 21 are greater each year that the inflation persists. In the second year of inflation, both the wool and dairy industry begin to show response effects. For the wool industry the effect in this year (a fall in gross value of production of $1.9m.) is repeated in larger doses in subsequent years. However, for the dairy industry the distributed lag on price means that the effect is spread over three years subsequent to the initial introduction of five per cent inflation.

In Table 22 below the cumulative effects are shown of four years of continuous inflation at the rate of five per cent per annum. Of interest is the large reduction in gross value of milk production

TABLE 22

Cumulative Four Year Effects of a Five Per Cent Per Annum Rate of Inflation.

Revenue	$m.	$m.
Gross value of wool production	-18.8	
Gross value of sheep and lambs slaughtered	-50.7	
Gross value of cattle and calves slaughtered	-71.9	
Gross value of milk production	-43.1	
Total		-184.5
Costs		
Marketing costs	+111.4	
Seed and fodder costs	+101.0	
Other farm costs n.e.i.	+387.1	
Total		+599.5
Farm Income		-784.0
G.N.P.		-990.2

which is brought about by a distributed lag effect on a progressively lower real price. Total supply response effects now account for 24 per cent of the fall in farm income which is significantly higher than the 17 per cent obtained in the first year of the inflation. The dominant item is still other farm costs n.e.i. which accounts for 49.4 per cent of the fall in farm income. The reason for the continued dominance of this item is the relatively large coefficient on the calculated price index for these costs in the cost equation (see summary of the model above). The cumulative fall in G.N.P. of $990.2m. represents an annual rate of $247.5m. which is 1.1 per cent of the status quo level. Thus it may be said that the national result of the effects of cost inflation in the farm sector are reasonably large compared with the effects of drought. The proportion of farm income lost is 17 per cent which may be quite a significant loss for industries dependent on agriculture and on the rural sector itself.

Influences of the Wool Industry

In the preceding sections of this chapter, the effects of both drought and inflation on gross value of wool production have been computed and used in estimating the effects of these phenomena on total farm income and G.N.P. The effects of these phenomena on wool income cannot be calculated because costs are not allocated on an industry basis. Furthermore, there seems to be little relevance in separating the wool effects on total farm income from the other industry effects in relation to drought and inflation. Accordingly it was felt that wool should not be isolated for special consideration in respect of these two simulations.

However, of special importance and significance to the wool industry are wool prices. In a much publicised depression in world demand, average wool prices in Australia fell by 21.6 per cent from 1969-70 to 1970-71. It is proposed in this section to simulate such a fall, rounding it to 20 per cent, and to study the effects on farm revenues, costs, income and G.N.P. The immediate effect of such a price fall is on wool revenue which falls by $150.8m. from its status quo level. In the same year as the fall in wool price there is a production response in the form of increased sheep and lamb slaughterings. The elasticity of demand was such that the subsequent price fall for sheep and lambs was more than proportional to the rise in slaughterings causing a net fall in revenue of $0.60m. Also, as a result of increased slaughterings, marketing costs (for sheep and lambs) rise by $1.8m. No other costs are significantly affected until the following year.

In summary, the total immediate fall in farm income is $153.2m. which is 13 per cent of the status quo level of farm income. The fall in G.N.P. is calculated at $193.5m. or 0.88 per cent of the status quo level. This is second in magnitude only to drought in the impact effect of simulations studied here. After the initial fall in wool prices, two possibilities were explored regarding their future course.

First, it was assumed that after the 20 per cent fall during the year, prices returned to and remained at their status quo level. This assumption has some similarity to recent Australian experience since after the 21.6 per cent fall from 1969-70 to 1970-71, prices recovered in 1971-72 to their level of 1969-70. After the year in which prices fall, there is no further response effect involving wool production or sheep and lambs for slaughter. However, for the following three years there is a progressively smaller increase in wheat acreage as growers shift into wheat and out of wool production. Consequent upon the increase in grain (wheat) acreage, there is an increase, with a one year lag, in sow numbers and pig slaughterings, and a consequent fall in pig prices. Thus it is four years before the lagged responses have worked themselves out and before the status quo is restored. In Table 23 below the cumulative effects on costs, revenues, farm income and G.N.P. are shown of the four years following the one year only 20 per cent fall in wool prices. Thus the response effects of sheep and lambs slaughtered is excluded as it occurred in the same year as the price fall.

TABLE 23

Cumulative Effects of a One Year 20 Per Cent Fall in Wool Prices

Revenue	$m.	$m.
Gross value of production of wool	-6.0	
Gross value of production of wheat	+32.8	
Gross value of pigs slaughtered	-0.3	
Total		+26.5
Costs		
Marketing costs	+2.7	
Seed and fodder costs	+5.7	
Other farm costs n.e.i.	+10.6	
Total		+19.0
Farm Income		+7.5
G.N.P.		+9.5

The reduction in the gross value of wool production is assumed to occur in the year immediately following the fall in price. It was the same for each year in relation to the old status quo and is the same as was obtained for the first simulation on wool prices above. The cumulative effect on sheep and lambs for slaughter is included in Table 24 since the response effect for this sector is now not limited to the first year of the fall but is repeated in every year.

The effects in Table 24 are again dominated by the increase in wheat production. The resultant rise in G.N.P. is three times as big as that obtained under the first assumption concerning the future course

TABLE 24

Cumulative Response Effects of a Permanent 20 Per Cent Fall In Wool Prices.

Revenue	$m.	$m.
Gross value of production of wool	-24.0	
Gross value of production of wheat	+119.8	
Gross value of sheep and lambs slaughtered	-2.4	
Gross value of pigs slaughtered	-1.0	
Total		+92.4
Costs		
Marketing costs	+10.4	
Seed and fodder costs	+21.0	
Other farm costs n.e.i.	+38.8	
Total		+70.2
Farm Income		+22.2
G.N.P.		+28.0

of wool prices. There is a limit to the extent of this effect which is imposed by the stability of world wheat prices in the face of expanding Australian production. The total net effect on G.N.P. using the first assumption about wool prices is a fall of $184.0m. compared with $165.5m. under the second assumption. In percentage terms these falls are just below 0.9 per cent of status quo G.N.P. and thus are not likely to greatly affect the national economy. However, they represent just over 10 per cent of farm income and thus may cause substantial regional problems.

Conclusions

In concluding this simulation chapter it must be pointed out that the effects on G.N.P. that were computed here are greatly dependent on the reduced form coefficient of farm income calculated from Zerby's 2SLS model (see Table 16 above). To the extent that Zerby's model is inaccurate then this coefficient is inaccurate. However, it is supported by the fact that the OLS reduced form coefficient is of the same order of magnitude. Thus it seems safe to suggest that the effects on the national economy of the types of changes simulated in this chapter are fairly slight. Since the cry of "Australia rides on the sheep's back" was first heard, the economy has greatly diversified both its internal structure and the structure of its foreign trade. Thus it is not surprising to find that in a production sense the rural sector has only minor effects on the rest of the economy.

The seasonal effects on bank liquidity and on unemployment of seasonality in rural production and incomes may be quite important.

However, to successfully investigate this aspect of the link between rural and non-rural Australia, a quarterly model employing sophisticated techniques such as cross-spectral analysis is needed. This study has shown that on an annual basis, such changes as have been recently adversely affecting agriculture, while important to the farm sector in magnitude, do not have significant effects on the size of the national product.

APPENDIX

LIST OF VARIABLES AND DATA USED IN REGRESSIONS

and

BIBLIOGRAPHY

APPENDIX

LIST OF VARIABLES AND DATA USED IN REGRESSIONS

List of Variables

WTA	acres planted to wheat, in thousands,
WFU	quantity of artificial fertiliser used on wheat divided by the number of acres under wheat which were fertilised, lb. per acre,
Pwt/Pwl	ratio of B.A.E. wheat price index to B.A.E. wool price index,
MTW	modified series of WFU,
CGA	acres planted to all coarse grains, in thousands,
Pog/Pwt	ratio of B.A.E. index of coarse grains prices to B.A.E. index of wheat prices,
SAC	acres of sugar cane cut for crushing, thousands of acres,
SX	exports of raw and refined sugar, thousands of tons,
FQP	quantum of fruit production, thousands of dollars, at average 1960-61 to 1962-63 prices,
FIP	percentage of the total area under fruit which is irrigated,
PF	undeflated B.A.E. index of prices received by farmers for all fruit,
VQP	quantum of vegetable production, thousands of dollars, at average 1960-61 to 1962-63 prices,
VPM	undeflated B.A.E. index of prices received by farmers for vegetables,

VFU	quantity of artificial fertiliser used on vegetables divided by the area under vegetables on which it was used, lb per acre,
AH	acres under hay, in thousands,
HSTK	stocks of hay at beginnings of years, in thousands of tons,
LVSK	index of livestock numbers at beginnings of years,
DMI	index of mortality due to drought in the sheep population,
ALDIS	variable obtained by applying an Almon distributed lag to DMI with a lag of five years and a peak in t-1,
TNF	variable measuring both size and fertility of the sheep population, millions
AP	average of past five years of area of sown grasses and clovers (improved pasture), millions of acres,
SLSH	number of sheep and lambs shorn, millions,
Pwl	B.A.E. index of prices received by farmers for wool, deflated by B.A.E. index of prices paid by farmers,
SLK	number of sheep and lambs slaughtered, thousands,
Psm	combination of B.A.E. indexes of prices received for sheep and lambs, deflated by B.A.E. index of prices paid by farmers,
YPDH	personal disposable income per head deflated by Consumer Price Index average 1960-61 to 1962-63 dollars,
MLX	exports of carcass mutton and lamb, thousands of tons,
NCS	number of cattle and calves slaughtered, thousands,
Pb	B.A.E. index of prices received by farmers for cattle deflated by B.A.E. index of prices paid by farmers,

ALPB	variable obtained by applying an Almon distributed lag to Pb with a lag of five years and a peak in t-5,
ALDI	variable obtained by applying an Almon distributed lag to DMI with a lag of five years and a peak in t-5,
BX	exports of carcass beef and veal, thousands of tons,
NSOW	sow numbers at the beginnings of years, thousands,
Pp/Pg	ratio of B.A.E. index of prices received for pigs to B.A.E. index of prices received for all grains,
TGA	total area under all grains, thousands of acres,
NPS	number of pigs slaughtered, thousands,
RPP	B.A.E. index of prices received for pigs deflated by B.A.E. index of prices paid by farmers,
QCH	quantum of poultry products, millions of dollars, average 1960-61 to 1962-63 prices,
Pch	B.A.E. index of prices received for poultry products deflated by B.A.E. index of prices paid by farmers,
WMP	total production of wholemilk for all purposes, millions of gallons,
Pd	B.A.E. index of prices received for dairy products deflated by B.A.E. index of prices paid by farmers,
TPN	mean fiscal population of Australia, thousands,
CPN	mean fiscal population of Australian capital cities, thousands,
YD	percentage deviation from trend of average milk yield per dairy cows,

MC	total marketing costs for rural products, millions of dollars,
QFM	quantum of rural production, valued at average 1960-61 to 1962-63 prices, millions of dollars,
Pmc	B.A.E. index of prices paid by farmers for marketing costs.
SFC	total seed and fodder costs, millions of dollars,
AC	area under all crops except fruit, million acres,
MLVSK	index of livestock numbers at the middle of the year,
Psf	B.A.E. index of prices paid by farmers for seed and fodder,
OFC	other farm costs not elsewhere included, millions of dollars,
TAC	total area under all crops, million acres,
FD	total rural debt to institutional lenders, millions of dollars,
PI	index of prices paid by farmers for other farm cost items.

Data Used

Year	WTA[a]	WFU[a]	Pwt/Pwl[b]	MTW[a]	CGA[a]	Pog/Pwt[b]
1946-47	13,179.6	71.56	134.09	87.0	2,856.4	110.17
1947-48	13,880.3	78.51	115.28	87.0	3,307.3	116.87
1948-49	12,583.5	84.27	103.41	87.0	3,016.2	81.32
1949-50	12,240.3	93.30	75.00	87.0	3,084.2	102.30
1950-51	11,663.2	87.77	35.50	87.0	3,176.1	123.66
1951-52	10,383.7	88.16	73.68	87.0	3,829.1	152.04
1952-53	10,209.5	89.98	71.33	87.0	4,510.5	114.95
1953-54	10,750.9	87.85	67.35	87.0	4,307.8	121.21
1954-55	10,672.6	90.66	68.99	87.0	4,651.0	137.08
1955-56	10,166.0	89.32	77.39	87.0	5,594.5	121.35
1956-57	7,874.2	91.88	62.33	87.0	5,037.3	118.68
1957-58	8,847.8	90.79	82.46	90.79	5,477.8	129.79
1958-59	10,399.2	89.31	109.09	89.31	6,786.7	102.08
1959-60	12,172.4	88.55	93.33	88.55	5,865.9	102.04
1960-61	13,438.9	88.16	104.21	88.16	6,906.4	98.99
1961-62	14,722.7	90.50	102.02	90.50	6,053.2	96.04
1962-63	16,468.6	92.29	95.33	92.29	5,920.4	102.94
1963-64	16,473.5	94.79	79.20	94.79	5,985.9	107.07
1964-65	17,918.6	98.32	92.38	98.32	6,119.4	112.37
1965-66	17,514.6	102.34	91.67	102.34	6,695.6	122.22
1966-67	20,822.8	105.49	98.08	105.49	7,459.8	107.84
1967-68	22,441.0	109.53	115.38	109.53	6,653.5	113.33
1968-69	26,799.5	111.87	104.08	111.87	7,844.8	105.88

a. Source: Either obtained directly or calculated from C.B.C.S., *Rural Industries Bulletin*, various issues.

b. Source: Either obtained directly or calculated from material supplied by B.A.E., base average of three years 1960-61 to 1962-63 = 100.

Data Used (Cont'd)

Year	SAC[a]	SX[a]	FQP[a]	FIP[a]	PF[b]	VQP[a]
1946-47	226.957	117.004	104.361	33.6	31	78.389
1947-48	222.941	100.351	128.347	34.3	40	74.989
1948-49	266.330	415.194	106.109	34.4	44	71.729
1949-50	281.329	432.711	107.587	35.1	46	70.276
1950-51	271.873	387.841	107.896	35.8	49	67.464
1951-52	281.724	167.431	112.389	38.0	50	76.133
1952-53	279.959	459.354	113.526	38.3	48	70.162
1953-54	340.490	706.796	133.267	37.7	53	74.213
1954-55	374.206	737.150	124.938	39.6	63	69.784
1955-56	372.774	502.229	128.647	40.2	77	66.655
1956-57	370.114	675.282	124.355	39.7	105	85.589
1957-58	375.719	707.802	141.523	40.0	94	87.690
1958-59	369.578	802.969	138.335	41.6	91	87.130
1959-60	313.980	701.316	142.935	41.9	90	88.882
1960-61	340.903	796.496	145.137	42.4	94	81.112
1961-62	386.878	843.530	170.412	43.5	105	91.857
1962-63	401.586	1,145.958	165.081	44.4	111	100.500
1963-64	417.568	1,116.170	183.050	45.6	105	93.483
1964-65	470.385	1,269.138	189.306	46.7	98	93.982
1965-66	503.199	1,252.543	184.473	48.9	110	104.643
1966-67	557.473	1,638.324	198.380	51.1	95	103.398
1967-68	553.009	1,597.240	193.803	52.6	95	105.358
1968-69	568.480	2,029.199	191.451	53.3	96	111.840

a. Source: Either obtained directly or calculated from C.B.C.S., Rural Industries Bulletin, various issues.

b. Source: Obtained directly from material supplied by B.A.E., base average of three years 1960-61 to 1962-63 = 100.

Date Used (Cont'd)

Year	VPM[a]	VFU[b]	AH[b]	HSTK[b]	LVSK[c]	DMI[d]
1946-47	43	665.51	2,005.8	2,162.7	72.32	119.24
1947-48	36	690.86	1,970.2	1,978.8	70.37	96.19
1948-49	47	713.84	1,579.5	2,735.0	73.09	97.00
1949-50	56	726.89	1,605.2	2,418.8	75.56	72.47
1950-51	61	694.50	1,377.2	2,445.6	78.22	147.92
1951-52	69	740.59	1,548.9	2,242.1	80.92	127.58
1952-53	99	757.76	1,761.3	2,353.6	80.03	67.16
1953-54	80	788.27	1,935.4	2,813.3	82.42	90.80
1954-55	90	771.11	1,984.4	3,113.2	84.76	76.05
1955-56	79	762.67	2,240.9	3,321.8	86.56	84.14
1956-57	135	767.66	1,861.4	3,909.0	90.40	102.61
1957-58	130	817.82	2,237.3	4,023.2	95.75	132.15
1958-59	68	779.01	3,018.1	3,142.4	94.44	84.67
1959-60	78	775.96	2,105.2	5,385.2	92.70	93.76
1960-61	79	781.69	2,973.0	4,368.3	94.27	95.88
1961-62	105	801.88	2,273.7	5,747.1	96.97	70.29
1962-63	110	798.09	2,720.3	4,923.3	100.62	98.02
1963-64	86	847.36	2,601.7	5,080.6	102.43	75.49
1964-65	90	870.96	2,792.5	4,804.9	105.64	74.86
1965-66	132	889.45	2,780.2	5,447.4	106.19	182.86
1966-67	126	903.26	3,495.9	4,301.8	100.34	71.68
1967-68	105	903.29	2,799.9	5,537.1	103.03	88.28
1968-69	130	929.89	3,955.0	3,410.8	107.33	67.31

a. Source: Obtained directly from material supplied by B.A.E., base average of three years 1960-61 to 1962-63 = 100.

b. Source: Either obtained directly or calculated from C.B.C.S., Rural Industries Bulletin, various issues.

c. Source: Calculated from C.B.C.S., Rural Industries Bulletin, various issues and C.B.C.S., Value of Production, Bulletin No.5, 1968-69

d. Source: Calculated from C.B.C.S., Livestock Numbers, various issues.

Data used (Cont'd)

Year	ALDIS[a]	TNF[b]	AP[b]	SLSH[b]	Pwl[c]	SLK[b]
1946-47	704.10	129.80	10.676	102.54	118.9	9,923.5
1947-48	708.98	129.14	10.758	105.07	180.0	8,468.9
1948-49	661.64	137.45	11.124	113.66	195.6	9,446.4
1949-50	587.72	144.38	11.843	118.41	232.0	10,471.0
1950-51	462.91	149.43	13.432	120.83	429.5	8,456.2
1951-52	480.33	152.61	13.428	121.93	168.4	9,082.0
1952-53	508.54	154.77	16.485	131.49	180.7	12,353.9
1953-54	470.46	161.87	18.044	132.62	175.0	12,438.8
1954-55	456.20	165.87	19.842	137.03	151.8	12,305.8
1955-56	422.08	171.94	21.295	141.51	133.7	11,377.5
1956-57	383.74	182.93	23.229	158.42	160.4	11,128.2
1957-58	392.33	196.66	25.845	160.58	120.0	14,354.7
1958-59	455.59	195.62	28.312	162.85	93.6	15,756.6
1959-60	451.15	201.38	30.376	169.49	109.4	19,526.1
1960-61	454.78	203.16	31.952	163.55	96.0	19,150.3
1961-62	450.65	201.51	33.501	169.78	99.0	19,060.9
1962-63	408.17	207.27	34.909	170.41	105.9	18,865.3
1963-64	400.63	208.35	36.498	176.05	123.8	18,776.3
1964-65	385.43	216.06	38.629	182.35	101.0	19,030.5
1965-66	368.06	223.60	41.403	176.07	98.2	20,933.0
1966-67	483.55	209.18	43.989	175.52	91.2	17,742.0
1967-68	468.72	217.95	46.470	180.68	77.1	22,268.9
1968-69	459.28	221.50	49.147	185.53	81.7	18,234.4

a. Calculated from DMI.

b. Source: Either obtained directly or calculated from C.B.C.S., Rural Industries Bulletin, various issues.

c. Source: Calculated from material supplied by B.A.E., base average of three years 1960-61 to 1962-63 = 100.

Data used (Cont'd)

Year	Psm[a]	YPDH[b]	MLX[c]	NCS[c]	Pb[a]	ALPB[d]
1946-47	153.24	745.40	73.349	3,164.2	83.78	281.03
1947-48	171.50	817.90	54.680	3,378.3	80.00	305.16
1948-49	130.22	842.49	52.279	3,494.3	84.44	329.85
1949-50	160.20	893.91	86.202	3,607.8	90.00	344.87
1950-51	209.18	954.56	24.156	3,735.0	91.80	367.94
1951-52	125.70	830.95	13.908	3,686.1	94.94	383.53
1952-53	126.63	871.27	74.484	3,966.2	79.52	392.38
1953-54	131.07	896.20	44,505	4,415.5	89.29	401.60
1954-55	140.24	929.81	57.497	4,484.5	92.94	405.87
1955-56	142.67	928.45	51.912	4,611.6	84.88	405.18
1956-57	132.64	941.90	34.051	4,952.4	75.82	400.39
1957-58	110.21	910.00	51,748	5,338.8	88,42	386.83
1958-59	97.98	943.69	89.717	5,872.4	103.19	393.07
1959-60	95.63	974.36	73.497	4,961.9	116.67	395.08
1960-61	114.04	990.48	88.681	4,277.5	119.19	404.74
1961-62	90.40	1,006.36	100.167	5,115.3	90.00	434.48
1962-63	96.14	1,045.57	134.304	5,931.2	92.08	469.25
1963-64	110.40	1,105.71	132.634	6,437.2	97.03	483.42
1964-65	120.00	1,117.14	141.363	6,844.2	103.85	476.87
1965-66	121.27	1,111.31	158.248	6,323.5	119.09	455.28
1966-67	111.84	1,155.27	150.004	5,650.2	120.18	439.58
1967-68	101.36	1,195.13	191.393	5,656.2	117.80	466.61
1968-69	85.92	1,224.42	172.390	5,608.3	116.67	495.35

a. Source: Calculated from material supplied by B.A.E., base average of three years 1960-61 to 1962-63 = 100.

b. Source: Calculated from C.B.C.S., Australian National Accounts, various issues, C.B.C.S., Labour Report, various issues and C.B.C.S., Demography Bulletin, various issues.

c. Source: C.B.C.S., Rural Industries Bulletin, various issues.

d. Calculated from Pb.

Data used (Cont'd)

Year	ALDI[a]	BX[b]	NSOW[c]	Pp/Pg[d]	TGA[b]	NPS[b]
1946-47	577.22	90.71	167	65.00	16,036.0	1,601.4
1947-48	655.57	116.54	157	52.94	17,187.6	1,558.2
1948-49	712.61	97.53	161	55.68	15,599.7	1,684.3
1949-50	730.43	93.93	151	71.26	15,324.5	1,567.6
1950-51	556.10	81.51	144	76.29	14,839.3	1,528.9
1951-52	467.51	51.73	155	91.59	14,212.8	1,499.9
1952-53	465.22	96.08	135	94.55	14,720.0	1,474.2
1953-54	472.21	154.77	142	106.80	15,058.7	1,545.2
1954-55	473.01	137.41	178	85.26	15,323.6	1,951.0
1955-56	490.85	163.26	176	117.39	15,760.5	1,827.5
1956-57	413.44	177.07	163	119.15	12,911.5	1,739.7
1957-58	367.87	155.20	198	89.90	14,325.6	2,076.8
1958-59	413.98	295.55	191	102.06	17,185.9	2,087.1
1959-60	426.29	261.76	179	120.41	18,038.3	2,042.5
1960-61	454.29	189.62	211	108.16	20,345.3	2,228.6
1961-62	470.39	299.33	236	85.00	20,775.9	2,573.1
1962-63	451.03	384.99	236	106.86	22,389.0	2,424.2
1963-64	399.40	422.98	208	116.00	22,459.4	2,313.5
1964-65	398.53	457.25	224	117.17	24,038.0	2,468.4
1965-66	382.11	412.00	252	117.48	24,210.2	2,777.3
1966-67	406.61	383.63	252	116.50	28.282.6	2,911.9
1967-68	447.87	380.83	263	118.52	29,094.5	3,057.6
1968-69	450.74	379.74	305	105.83	34,744.3	3,319.2

a. Calculated from DMI.

b. Source: Either obtained directly or calculated from C.B.C.S., Rural Industries Bulletin, various issues.

c. Source: Obtained directly from C.B.C.S., Livestock Numbers, various issues.

d. Source: Calculated from material supplied by B.A.E., base average of three years 1960-61 to 1962-63 = 100.

Data used (Cont'd)

Year	RPP[a]	QCH[b]	Pch[a]	WMP[c]	Pd[a]	TPN[d]
1946-47	105.41	114.566	110.81	1,078.7	118.92	7,518
1947-48	112.50	102.735	130.00	1,172.2	127.50	7,639
1948-49	108.89	110.771	124.44	1,208.9	124.44	7,796
1949-50	124.00	106.324	126.00	1,238.4	120.00	8,044
1950-51	121.31	99.880	122.95	1,197.8	113.11	8,303
1951-52	124.05	99.018	124.05	1.047.4	115.19	8,529
1952-53	125.30	109.736	120.48	1,215.2	122.89	8,734
1953-54	130.95	111.040	117.86	1,189.6	121.43	8,900
1954-55	95.29	106.155	114.12	1,325.8	116.47	9,090
1955-56	125.58	105.496	118.60	1,402.0	115.12	9,316
1956-57	123.08	105.763	114.29	1,357.9	105.49	9,535
1957-58	93.68	103.679	112.63	1,264.4	105.26	9,742
1958-59	105.32	104.339	111.70	1,370.2	108.51	9,948
1959-60	122.92	108.795	114.58	1,406.6	106.25	10.164
1960-61	107.07	126.396	104.04	1,339.3	101.01	10,391
1961-62	85.00	120.517	101.00	1,443.6	99.00	10,645
1962-63	107.92	127.454	96.04	1,467.8	99.01	10,847
1963-64	114.85	135.473	100.99	1,496.4	101.98	11,059
1964-65	111.54	146.197	90.38	1,520.9	100.96	11,279
1965-66	110.00	156.165	90.00	1,522.0	95.45	11,501
1966-67	105.26	178.011	85.96	1,604.7	92.11	11,708
1967-68	108.48	185.471	78.81	1,497.5	87.29	11,927
1968-69	90.83	192.645	77.50	1,530.6	84.17	12,172

a. Source: Calculated from material supplied by B.A.E., base average of three years 1960-61 to 1962-63 = 100.

b. Source: Calculated from C.B.C.S., Value of Production, various issues and material supplied by B.A.E.

c. Source: C.B.C.S., Rural Industries Bulletin, various issues.

d. Source: C.B.C.S., Demography Bulletin, various issues.

Data Used (Cont'd)

Year	CPN[a]	YD[b]	MC[c]	QFM[d]	Pmc[e]	SFC[c]
1946-47	3,825	2.28	-	-	-	-
1947-48	3,895	7.93	-	-	-	-
1948-49	3,975	6.37	111.5	1,887.3	43	111.2
1949-50	4,079	5.16	135.0	1,994.8]	47	120.5
1950-51	4,175	-0.05	161.0	1,899.2	59	149.2
1951-52	4,256	-11.12	188.0	1,810.3	74	186.5
1952-53	4,332	3.06	244.8	2,094.3	84	195.0
1953-54	4,845	-5.39	223.2	2,159.4	90	214.2
1954-55	4,984	1.20	217.2	2,165.4	89	209.8
1955-56	5,129	2.90	233.0	2,315.9	90	214.0
1956-57	5,271	-4.40	229.8	2,305.4	94	234.0
1957-58	5,407	-11.92	235.8	2,219.1	93	260.7
1958-59	5,548	-3.79	281.5	2,668.6	92	229.0
1959-60	5,689	-0.97	286.5	2,552.9	96	271.0
1960-61	6,303	-5.48	315.8	2,677.1	101	288.5
1961-62	6,451	0.62	323.8	2,740.9	100	288.5
1962-63	6,608	-0.93	343.5	2,954.4	101	290.0
1963-64	6,775	-1.56	359.5	2,080.1	104	310.5
1964-65	6,945	-0.69	379.0	3,249.1	107	340.8
1965-66	7,117	1.20	377.8	2,980.5	110	401.8
1966-67	7,272	7.59	409.2	3,460.1	114	389.8
1967-68	7,435	1.17	385.2	3,067.5	116	409.8
1968-69	7,645	5.37	483.0	3,725.4	118	282.2

a. Source: C.B.C.S., Demography Bulletin, various issues.

b. Source: Calculated from C.B.C.S., Rural Industries Bulletin, various issues.

c. Source: Calculated from C.B.C.S., Australian National Accounts, various issues.

d. Source: Calculated from C.B.C.S., Rural Industries Bulletin, various issues and C.B.C.S., Value of Production, Bulletin No.5, 1968-69.

e. Source: Obtained directly from material supplied by B.A.E.

Data Used (Cont'd)

Year	AC[a]	MLVSK[b]	PSF[c]	OFC[d]	TAC[a]	FD[e]
1946-47	-	-	-	-	-	-
1947-48	-	-	-	-	-	-
1948-49	20.502	74.33	50	325.9	20.924	418
1949-50	20.401	76.89	54	372.2	20.816	415
1950-51	19.722	79.58	73	438.0	20.133	456
1951-52	19.641	80.49	95	530.2	20.047	509
1952-53	20.259	81.23	97	612.2	20.666	557
1953-54	21.116	83.59	94	655.0	21.527	567
1954-55	21.927	85.66	95	678.8	22.339	676
1955-56	22.559	88.48	91	707.8	22.973	776
1956-57	19.560	93.08	94	754.0	19.962	798
1957-58	21.770	95.10	109	785.0	22.177	803
1958-59	25.213	93.57	95	787.0	25.631	917
1959-60	25.686	93.49	95	818.8	26.105	920
1960-61	29.156	95.62	102	850.5	29.576	974
1961-62	29.212	98.80	100	889.0	29.639	985
1962-63	31.654	101.53	99	938.8	32.092	1,040
1963-64	31.599	104.04	97	989.0	32.045	1,078
1964-65	34.215	105.92	100	1,061.2	34.665	1,138
1965-66	34.045	103.27	111	1,139.8	34.498	1,290
1966-67	39.101	101.69	108	1,231.5	39.553	1,398
1967-68	39.717	105.18	114	1,314.0	40.168	1,590
1968-69	46.485	110.77	110	1,386.2	46.939	1,857

a. Source: C.B.C.S., Rural Industries Bulletin, various issues.

b. Source: Calculated from LVSK.

c. Source: Obtained directly from material supplied by B.A.E., base average of three years 1960-61 to 1962-63 = 100.

d. Source: C.B.C.S., Australian National Accounts, various issues.

e. Source: Reserve Bank of Australia, Statistical Bulletin - Financial Supplement, various issues.

Data Used (Cont'd)

Year	PI[a]
1946-47	-
1947-48	-
1948-49	46.8
1949-50	51.3
1950-51	61.2
1951-52	75.7
1952-53	82.9
1953-54	83.1
1954-55	83.2
1955-56	86.6
1956-57	91.7
1957-58	94.1
1958-59	94.8
1959-60	96.2
1960-61	98.6
1961-62	100.7
1962-63	100.8
1963-64	100.1
1964-65	104.0
1965-66	109.8
1966-67	115.1
1967-68	118.9
1968-69	121.5

a. Source: Calculated from material supplied by B.A.E., base average of three years 1960-61 to 1962-63 = 100.

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