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# A SUPPLY FUNCTION FOR DAIRY PRODUCTS

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Results of an investigation into factors affecting the aggregate supply of dairy products in Australia are presented. Empirical estimates of the parameters of the supply function, using ordinary least squares, indicate that some concept of average prices for dairy products is a more important determinant of supply than ratios of prices of dairy products relative to prices of production substitutes such as beef cattle or sheep and lambs. The empirical results also indicate that the quota-type effects of the various metropolitan fluid milk schemes are important in determining supply. Effects of new technology on supply could not be quantified due to intercorrelation of explanatory variables.

## *Introduction*

Since the historic work of Powell and Gruen<sup>1</sup> Australian researchers have paid very little attention to estimating the parameters of supply and demand functions for agricultural commodities. Recent efforts have tended to concentrate on commodities not covered by the model presented by Powell and Gruen.<sup>2</sup> The most likely explanation for this state of affairs is that it is believed that the Powell and Gruen work has provided us with most of the supply and demand parameters that we need for projections or predictions. However, some serious questions have been raised concerning the statistical and other characteristics of their estimates.<sup>3</sup> A major fault in the Powell and Gruen approach is its inability to allow for institutional factors which affect supply decisions made at the farm level. Hence there is scope for much re-investigating to be done on the supply side. The present author believes that there is much to be gained from a commodity by commodity approach to agricultural supply analysis, incorporating structural and institutional considerations at each step. It is by such an approach that a body of knowledge about supply parameters in the farm sector can gradually be accumulated. This study presents some results of applying such an approach to the dairy industry in Australia.

\* The author is indebted to F. G. Jarrett and R. K. Hefford for comments on an earlier draft. Also, the paper has benefited from the constructive comments of a referee. This study is part of a wider piece of research, the aim of which is to develop an econometric model of the Australian farm sector.

<sup>1</sup> For a 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*, 46 (116), Dec. 1970, p. 563.

<sup>2</sup> See for example Taplin, J. H. E., and Smallhorn, P., 'The Supply of Honey in Australia', *Qu. Rev. of Ag. Econ.*, XXIII (2), 1970, pp. 97-109 and Knight, R. C., and Taplin, J. H. E., 'Supply Response in the Peanut Industry: A Linear Programming Approach', *Qu. Rev. of Ag. Econ.* XXIV (2), Apr. 1971, pp. 112-122.

<sup>3</sup> See Watson, A. S., Harcourt, G. C., and Praetz, P. D., *op. cit.*

*The Supply Model*

Logically, a supply study of the dairy industry should be composed of two parts: (a) domestic wholemilk supply and (b) 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 for the whole farm sector 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 supply to manufacturers, milk produced over and above their 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.

The choice of total wholemilk produced as the dependent variable for regression analysis was dictated largely by data availability. In most farm sectors there is a key variable which most readily reflects farm production decisions. For crops it 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 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 supply equations, it was decided to adopt the production variable as the dependent variable rather than attempt to synthesize 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 adequate 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.<sup>4</sup> 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 licences and delivery requirements to producers. On a per head of total population basis,

<sup>4</sup> There is evidence of a weak downward trend over time.

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<sup>5</sup> 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.

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.<sup>6</sup> 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.

A problem which faces every empirical investigator into agricultural supply is how to account for the influence of weather. 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 a 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 but this was not found to be so when applying the method to the dairy industry.

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<sup>7</sup> 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.

A final approach seeks to find a variable which can be taken as a broad surrogate for the various effects of weather on production. Two such surrogates were tried in this study. The first is a drought index which was developed by Powell and Gruen. The index is obtained by calculating the annual crude mortality rate for the Australian sheep

<sup>5</sup> Gruen, F. H., 'The Major Livestock Industries', p. 402, in Moore, R. Milton (ed.), *Australian Grasslands*, A.N.U. Press, Canberra, 1970.

<sup>6</sup> Statement by Warne, R. K. in *National Agricultural Outlook Conference, Contributed Papers*, Bureau of Agricultural Economics, Canberra 1971, p. F-8.

<sup>7</sup> For an application of this approach see Guise, J. W. B., 'Factors Associated With the Variation in the Aggregate Average Yield of New Zealand Wheat, 1918-1967', *Am. Jnl. of Ag. Econ.*, 51(4), Nov. 1969, pp. 866-881.

population and expressing each calculated rate as a deviation from the long term average rate. A high positive value thus indicates generally unfavourable weather. Use of this index in this study 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 and 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<sup>8</sup> and it is assumed that aberrations from trend were purely 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 Bureau of Agricultural Economics' index of prices received for dairy products deflated by the Bureau's 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.<sup>9</sup> To allow for the fact that total adjustment may not occur within one year, an expectations formulation was also tried. The expectations formula was as follows:

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

where  $EP_t$  is the index of price expected in period  $t$ ,  $P_t$  is the price to which the formula is applied and  $w$  is the coefficient of expectation.

This formula is simply a truncated version of the Nerlovian distributed lag model with an arbitrary limit of  $n$  time periods placed on the length of the lag. Repeated values of  $EP_t$  can be calculated by re-iterating on arbitrary values of  $n$  and  $w$  until the 'best fit'  $EP_t$  is found. The advantages of this approach to distributed lags are: (a) that it removes the need to have a lagged value of the dependent variable as an explanatory variable and the concomitant statistical problems<sup>10</sup> and (b) that it enables the inclusion of other explanatory variables besides price without causing the regression equation to become algebraically messy. In this study  $EP_t$  was calculated for values of  $n$  of three and five years and for values of  $w$  of 0.3, 0.5, 0.7 and 1.0 and regressions were run for each value.

In addition to the deflated dairy products price index, regressions were run using the ratio of the dairy products price index to the Bureau of Agricultural Economics' price index for beef cattle, both lagged one year, and in expectations formulations. This follows Powell's and

<sup>8</sup> The squared coefficient of correlation between milk yield per dairy cow and time over the period 1946-47 to 1968-69 was 0.84.

<sup>9</sup> 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.

<sup>10</sup> See Nerlove, Marc and Wallis, Kenneth F., 'Use of the Durbin-Watson Statistic in Inappropriate Situations', *Econometrica*, 34(1), Jan. 1966, pp. 235-8.

Gruen's claim<sup>11</sup> that this ratio is a powerful explainer of the supply of dairy products. Also tried was the ratio of dairy products price index to the average of the Bureau of Agricultural Economics' 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.

### *The Results*

Detailed tables of regression coefficients, their standard errors and other relevant results of the major regression analyses are presented in the appendix below. In the discussion that follows some principal features of the results will be highlighted and a selection will be made of the most useful models for explanation and prediction.

In all the regressions which were run, the estimated coefficient on the lagged, deflated price index (*PD*) had the expected positive sign and was statistically significant at five per cent or better. However, Table 1 of the appendix shows the estimated coefficients on the lagged price ratios to be positive but not significant at five per cent. This indicates that rewards to alternative uses of resources may not be so important as the price of dairy products themselves in determining wholemilk supply. This suggestion was reinforced by regressions in which the expectations formula was applied to the price ratios, the coefficients on all expected price ratios being statistically not significantly different from zero at 5 per cent. Observers close to the industry will not be surprised at this result as the high level of subsidization 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.<sup>12</sup> While on an aggregate basis the total value of output of the two industries has been about the same in recent years (around \$500 m. 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.<sup>13</sup> 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

<sup>11</sup> Powell, A. A., and Gruen, F. H., 'Problems in Aggregate Agricultural Supply Analysis: I—The Construction of Time Series for Analysis', *Rev. Marketing and Ag. Econ.*, 34(3), Sept. 1966, p. 135.

<sup>12</sup> 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. 6-24 and 6-25.

<sup>13</sup> 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.

compared to numbers of dairy cattle.<sup>14</sup> This 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.

Table 1 in the appendix also indicates that the area of improved pasture (IMP) is a poor explanator of the supply of wholemilk. In all regressions in which this variable was tried, 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 pasture is high and positive, however, the partial correlation coefficients, with other variables held constant, are 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 capital city population variable (CPN) and improved pasture. There is a strong time trend evident in these variables and it seems reasonable to suppose that effects of technical progress and diffusion of new techniques such as improved 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 subsidization 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 subsidization 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.

According to Johnston, the effect of this multicollinearity should be to reduce the 'degree of precision' attaching to the estimate of the coefficients. Since the coefficient on CPN is significant in every case in Table 1, and since Johnston himself says<sup>15</sup> 'if forecasting is a primary objective, then intercorrelation of explanatory variables may not be too serious, provided it may reasonably be expected to continue in the future', it is suggested that multicollinearity is not a serious fault in these models. From a forecasting viewpoint, this conclusion is contingent on the time trend remaining in the variables. The results presented in Tables 2, 3 and 4 in the appendix are for models which exclude the pasture variable on the assumption that the multicollinearity will continue.

Comparisons of the performance of the two population variables show

<sup>14</sup> Commonwealth Bureau of Census and Statistics, 'Classification of Rural Holdings by Size and Type of Activity, Bulletin No. 7, 1965-66'. Canberra, 1968, 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.

<sup>15</sup> Johnston, J., *Econometric Methods*, McGraw-Hill, 1963, p. 207.

that there was a generally better fit (higher  $R^2$ ) for models containing *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. Also operating against *TPN* was the fact that in two models where it was used, the last two models in Table 3 in the appendix, 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 2 in which *CPN* was used, the Durbin-Watson statistic is indicative of negative autocorrelation. While it is recognized that estimating techniques do exist for getting around the problem of autocorrelation, it is felt that these methods should only be resorted to if alternative specifications do not give satisfactory results. Such specifications are presented in the Tables. 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.

Comparisons between Table 2 and Tables 3 and 4 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 5 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 4). 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' model would seem to be represented by column one in Table 4. All coefficients in this model are significant and of the anticipated sign, the explanation is high ( $R^2 = 0.93$ ) and the model is 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 2. Both of these feature reasonable fit ( $R^2 = 0.86$ ), statistically significant coefficients and absence of any indication of autocorrelation. They also both employ *TPN* as the population variable.

### Conclusions

This study has shown that useful and statistically significant models of supply in the dairy industry can be developed on a single equation basis employing some very little knowledge about institutional factors in the industry. The effects of price, weather and city milk boards have been successfully and separately quantified. Due to multicollinearity, the effects of technology could not be quantified and it is recommended that any forecasts which are made using the models presented here be contingent upon the continuance of the multicollinearity.



## APPENDIX

*Variables Used and Regression Results*

The dependent variable in every model was annual production of wholemilk for Australia, in millions of gallons over the period 1946-47 to 1968-69. Source of the production data was Commonwealth Bureau of Census and Statistics, Rural Industries Bulletin No. 7, 1968-69.

$PD_{t-1}$	The Bureau of Agricultural Economics' dairy products price index deflated by the Bureau's index of prices paid by farmers, lagged one year.
$Pd/Pb_{t-1}$	The ratio of B.A.E. dairy products price index to B.A.E. price index for beef cattle, lagged one year.
$Pd/Ps_{t-1}$	The ratio of B.A.E. dairy products price index to B.A.E. price index for sheep and lambs, lagged one year.
$E(PD)$	The index of expected value of $PD$ obtained using the expectations formula outlined above for $w = 0.3$ and $n = 3.0$ . These values of $w$ and $n$ were found to give a value of $E(PD)$ which resulted in best fits in all regression equations.
$IMP_{t-1}$	The average of the past five years of the area under sown grasses and clovers.
$TPN_{t-1}$	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 $t - 1$ .
$DMI_t$	Index of drought based on sheep mortality.
$YD_t$	Index of weather based on divergence from trend of milk yield per dairy cow.

In all results below the standard errors are in brackets.

\* Denotes significance at the five per cent level.

† Denotes significance at the one per cent level.

TABLE 1

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

Explanatory Variable	Regression Coefficients and Standard Errors		
$PD_{t-1}$	8.9† (2.5)		
$Pd/Pb_{t-1}$		0.7 (1.1)	
$Pd/Ps_{t-1}$			1.6 (0.9)
$IMP_{t-1}$	-1.3 (6.9)	-6.6 (8.9)	-11.2 (8.1)
$CPN_{t-1}$	0.2† (0.07)	0.2* (0.08)	0.2* (0.08)
$R^2$	0.91	0.86	0.87
Durbin-Watson Statistic	2.59	2.03	1.79

TABLE 2

*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*	7.7†		
	(2.6)	(2.1)		
$PD_{t-1}$			6.7*	9.1*
			(3.0)	(2.4)
$TPN_{t-1}$	0.2†		0.1†	
	(0.02)		(0.02)	
$CPN_{t-1}$		0.2†		0.2†
		(0.02)		(0.02)
$R^2$	0.86	0.91	0.86	0.92
Durbin-Watson Statistic	1.93	2.57	1.96	2.59

TABLE 3

*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	-0.6		
	(0.4)	(0.4)		
$YD_t$			7.7†	7.3†
			(1.7)	(1.7)
$E(PD)$	5.8*		6.0†	
	(2.5)		(1.8)	
$PD_{t-1}$		6.4†		6.3†
		(2.9)		(2.2)
$TPN_{t-1}$	0.2†	0.1†	0.2†	0.1†
	(0.03)	(0.02)	(0.02)	(0.02)
$R^2$	0.87	0.87	0.93	0.92
Durbin-Watson Statistic	1.62	1.66	0.94	1.01

TABLE 4

*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*	0.6		
	(0.3)	(0.3)		
$YD_t$			4.7†	4.4*
			(1.6)	(1.6)
$E(PD)$	7.7†		6.8†	
	(1.9)		(1.8)	
$PD_{t-1}$		8.3†		7.8†
		(2.2)		(2.1)
$CPN_{t-1}$	0.2†	0.2†	0.2†	0.2†
	(0.02)	(0.02)	(0.02)	(0.02)
$R^2$	0.93	0.93	0.94	0.94
Durbin-Watson Statistic	2.31	2.27	1.57	1.59