MARKETING MARGINS AND MARKET POWER IN THE AUSTRALIAN DAIRY PROCESSING AND RETAILING SECTORS

by

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Abstract

We use a New Empirical Industrial Organisation (NEIO) approach to estimate industry marketing margins for several Australian dairy products. Our model allows for differences in input- and output-market conjectural elasticities under the assumption of a fixed proportions production technology. Other assumptions on the production technology include the use of a single agricultural input to produce multiple outputs, and substitutability between agricultural and non-agricultural inputs. Two alternative methods are used to decompose the price of manufacturing milk into the prices of components used to produce different manufacturing milk products. We estimate margins equations for carton milk, whole-milk powder (WMP), butter, cheese and skim-milk powder (SMP) using state-level data. Nonlinear least squares is used to impose a number of inequality constraints implied by economic theory. The results suggest that, in price-deregulated markets, only three market intermediaries possess market power: carton milk retailers possess market power in output markets; carton milk processors possess market power in both input and output markets; and butter processors possess market power in input markets.

Paper prepared for the 43rd Annual Conference of the AARES, Christchurch, New Zealand, 20-22 January 1999. The author acknowledges the generous assistance of Kate Owen who extended and updated an earlier data set used by O'Donnell and Coelli (1997).

1. INTRODUCTION

Analysis of market power in non-competitive food industries is increasingly being conducted within a New Empirical Industrial Organisation (NEIO) (Bresnahan, 1989) framework. A feature of the NEIO approach is the use of econometric models to estimate parameters of industry marginal cost functions and measures of industry conduct. Most NEIO studies measure industry conduct by way of conjectural elasticities (ie. the percentage changes in industry output resulting from one-percentage changes in the outputs of individual firms). This approach has been used by Schroeter (1988) and Schroeter and Azzam (1991) to analyse firm conduct in the U.S. meat industry, and by Wann and Sexton (1992) to analyse behaviour in the U.S. pear processing industry. In this paper we apply the NEIO methodology to the Australian dairy retailing and processing industry. Our choice of empirical application has been motivated by recent moves to eliminate price controls on milk products in some Australian states.

A limitation of many NEIO studies is that the assumed form of the production technology is very simplistic. Schroeter and Azzam, for example, assume that a single homogenous agricultural input is combined with non-agricultural inputs to produce a single homogenous output. Wann and Sexton assume that agricultural and non-agricultural inputs are non-substitutable in the production process. Our choice of empirical application forces us to abandon these assumptions in favour of assumptions which allow a single agricultural input (eg. manufacturing milk) to be combined with non-agricultural inputs (eg. labour and capital) to produce several outputs (eg. butter, cheese and powdered milk). We also assume that all inputs are substitutable.

A second limitation of many NEIO studies is that the conjectural elasticities used to measure firm conduct in input and output markets are assumed to be equal. Differing degrees of firm concentration in agricultural input and output markets (arising from differences in geographical scope) usually make this assumption untenable. Wann and Sexton argue that the assumed equivalence of input- and output-market conjectural elasticities is usually a corrollary of a fixed proportions assumption on the production technology. This paper shows how input- and output-market conjectural elasticities can still differ under a fixed proportions assumption.

The fixed proportions assumption is only one of many assumptions we make concerning demands in output markets, supplies in input markets and the production technologies of market intermediaries. Some of the important assumptions which make our empirical model tractable are that output demand functions are linear in prices, input supply functions are linear in the squares of prices (a special case of a normalised quadratic supply function), and the production technologies of market intermediaries exhibit constant returns to scale. Less important assumptions are that the production technologies of market intermediaries are normalised quadratic, and all inputs are normal (ie. increases in outputs are associated with increases in all inputs). Many of these assumptions are commonplace in the agricultural economics literature. Importantly, they make it possible to derive linear industry marketing margins equations from the first-order conditions for profit maximisation by individual firms.

Our empirical work involves the estimation of industry marketing margins equations for carton milk, whole-milk powder (WMP), butter, cheese and skim-milk powder (SMP), using state-level data. The estimation process is complicated by our assumption that a single agricultural input can be used to produce multiple outputs. Thus, the margin for each output must be calculated as the difference between the output price and an unknown proportion of the single input price. In this paper we use two methodologies (one deterministic and one stochastic) to decompose the price of manufacturing milk into the prices of components used to produce different manufacturing milk products. Nonlinear least squares is then used to estimate the parameters of our margins equations subject to a number of inequality constraints implied by economic theory. Our results suggest that carton milk processors possess market power in the purchase and sale of market milk. Carton milk retailers also possess market power in the sale of market milk. We find that butter processors have market power in the purchase of manufacturing milk, but no other market intermediaries possess market power in either input or output markets.

The outline of the paper is as follows. Our theoretical model of margins behaviour in the retail and processing sectors is presented in Section 2. This section gives explicit consideration to the effects of price regulation at the farmgate level. Estimation methods are discussed in Section 3. Data collection procedures are presented in Section 4. Results are presented in Section 5 and the paper is concluded in Section 6.

2. THEORETICAL MODEL

In this section we develop a theoretical model of marketing margins determination predicated on assumptions concerning the production technologies and behavioural objectives of economic agents. For ease of exposition, and without loss of generality, the model is presented in the context of the Australian dairy industry. Our interest centres on the form of empirical marketing margins equations in price-deregulated markets and in markets where a regulating authority sets the price of market milk at the farm-processor point of exchange.

2.1 Deregulated markets

Let the subscripts m = 1, …, 5 denote carton milk, whole-milk powder (WMP), butter, cheese and skim-milk powder (SMP). Also let p_m represent the price of output m, w_m the price of input m, Q_m the aggregate quantity of output m, and X_m the aggregate quantity of input m. We assume that demand in the output market can be described by a demand function of the form:

(1) $Q_m = g_m(p_m) \qquad m = 1, \ldots, 5$

implying an inverse demand function of the form

(2) $p_m = g_m^{-1}(Q_m) \qquad m = 1, \ldots, 5.$

Market intermediaries (retailers and/or processors) are assumed to face dairy-input supply functions of the form

(3) $X_m = d_m(w_1, \ldots, w_5) \qquad m=1, \ldots, 5.$

We assume that n = 1, …, N market intermediaries produce output vectors $\mathbf{q}_n = (q_{n1}, \ldots, q_{n5})'$ using the vectors of dairy inputs $\mathbf{x}_n=(x_{n1}, \ldots, x_{n5})'$ together with vectors of non-dairy variable inputs (eg. labour and materials). The prices of these non-dairy variable inputs are included with firm invariant non-price exogenous variables in the (K×1) vector $\mathbf{z}$. The production relationship between each output and agricultural input is assumed to be one of fixed proportions, implying it is possible to measure output prices and input quantities in units which make input and output quantities directly comparable, implying $x_{nm} = q_{nm}$ for m=1, …, 5. Thus, aggregate outputs and inputs are

$$(4) \qquad Q_m = \sum_{n=1}^{N} q_{nm} = \sum_{n=1}^{N} x_{nm} = X_m \qquad m = 1, \ldots, 5$$

and the inverse demand function (2) becomes

$$(5) \qquad p_m = g_m^{-1}\left(\sum_{n=1}^{N} q_{nm}\right)$$

implying

$$(6) \qquad \partial p_m/\partial q_{nj} = 0 \quad \text{for all } j \neq m.$$

The assumption of fixed proportions also means that the profit of firm n can be written:

$$(7) \qquad \pi_n = \sum_{m=1}^{5} (p_m q_{nm} - w_m x_{nm}) - c(\mathbf{z}, \mathbf{q}_n) = \sum_{m=1}^{5} (p_m - w_m) q_{nm} - c(\mathbf{z}, \mathbf{q}_n)$$

where $c(\mathbf{z}, \mathbf{q}_n)$ is a retailing and/or processing cost function, measuring the cost of purchasing non-dairy inputs. Using (6), the first order conditions can be written

$$(8) \qquad (p_j - w_j) + (\partial p_j/\partial q_{nj}) q_{nj} - \sum_{m=1}^{5} (\partial w_m/\partial q_{nj}) q_{nm} - \partial c(\mathbf{z}, \mathbf{q}_n)/\partial q_{nj} = 0 \qquad j = 1, \ldots, 5.$$

If the margin is defined as $m_j \equiv p_j - w_j$ then equation (8) can be rewritten

$$(9) \qquad m_j = \partial c(\mathbf{z}, \mathbf{q}_n)/\partial q_{nj} - (\partial p_j/\partial q_{nj}) q_{nj} + \sum_{m=1}^{5} (\partial w_m/\partial q_{nj}) q_{nm}$$

$$= \partial c(\mathbf{z}, \mathbf{q}_n)/\partial q_{nj} - (\partial p_j/\partial Q_j)(\partial Q_j/\partial q_{nj})(q_{nj}/Q_j) Q_j + \sum_{m=1}^{5} (\partial w_m/\partial X_j)(\partial X_j/\partial x_{nj})(x_{nj}/X_j) Q_j (q_{nm}/q_{nj})$$

$$= \partial c(\mathbf{z}, \mathbf{q}_n)/\partial q_{nj} - Q_j \eta_j^{-1} \theta_{qnj} + Q_j \sum_{m=1}^{5} \varepsilon_{jm}^{-1} \theta_{xnj} q_{nm}/q_{nj}$$

where use has been made of the results that $x_{nj} = q_{nj}$ and $X_j = Q_j$. In equation (9), $\eta_j = \partial Q_j/\partial p_j$ is the slope of the consumer demand function for product j, $\varepsilon_{jm} = \partial X_j/\partial w_m$ is the slope of the input supply function for input j with respect to the price of input m, and θ_{qnj} and θ_{xnj} are conjectural elasticities which can be used as indexes of competition in output and input markets respectively. In output markets, values of $\theta_{qnj} = 0$ and $\theta_{qnj} = 1$ represent the extremes of perfect competition and monopoly or cartel behaviour respectively. In input markets, values of $\theta_{xnj} = 0$ and $\theta_{xnj} = 1$ represent the extremes of perfect competition and monopsony. For a motivation and interpretation of firm conjectural elasticities see, for example, Holloway (1991).

If the demand function given by (1) is linear in prices and the supply function given by (3) is linear in the square of prices (ie. a restricted version of a quadratic supply function) then η_j is a constant and ε_{jm} is proportional to w_m, meaning it is possible to write $\varepsilon_{jm}^{-1} = b_{jm}/w_m$. This result will prove useful below.

An industry-wide counterpart to equation (9) can be obtained by multiplying through by q_{nj}, summing over all N firms, and dividing by $Q_j = \sum_{n=1}^{N} q_{nj}$ to obtain

$$(10)\qquad m_j = \frac{\sum_{n=1}^{N} (\partial c(\mathbf{z}, \mathbf{q}_n)/\partial q_{nj}) q_{nj}}{\sum_{n=1}^{N} q_{nj}} - Q_j \eta_j^{-1} \frac{\sum_{n=1}^{N} \theta_{qnj} q_{nj}}{\sum_{n=1}^{N} q_{nj}} + \sum_{m=1}^{5} Q_m \varepsilon_{jm}^{-1} \frac{\sum_{n=1}^{N} \theta_{xnj} q_{nm}}{\sum_{n=1}^{N} q_{nm}}$$

$$= \frac{\sum_{n=1}^{N} (\partial c(\mathbf{z}, \mathbf{q}_n)/\partial q_{nj}) q_{nj}}{\sum_{n=1}^{N} q_{nj}} - Q_j \eta_j^{-1} \bar{\theta}_{qjj} + \sum_{m=1}^{5} Q_m \varepsilon_{jm}^{-1} \bar{\theta}_{xjm}$$

where $\bar{\theta}_{qjm}$ and $\bar{\theta}_{xjm}$ are the quantity weighted averages of firm conjectural elasticities obtained using product m quantities as weights.

If the cost function is normalised quadratic then

$$c(\mathbf{z}, \mathbf{q}_n) = a_0 + \sum_{m=1}^{5} a_m q_{nm} + \sum_{k=1}^{K} b_k z_k + 0.5 \sum_{m=1}^{5} \sum_{p=1}^{5} a_{mp} q_{nm} q_{np} + 0.5 \sum_{k=1}^{K} \sum_{j=1}^{K} b_{kj} z_k z_j + \sum_{m=1}^{5} \sum_{k=1}^{K} c_{mk} q_{nm} z_k$$

where all prices in the vector **z** have been normalised by dividing through by the consumer price index (‘netput 0’). Thus

(11) $$\partial c(\mathbf{z}, \mathbf{q}_n)/\partial q_{nj} = a_j + \sum_{p=1}^{5} a_{jp}q_{np} + \sum_{k=1}^{K} c_{jk}z_k$$

Finally, if the production technology exhibits constant returns to scale then $c(\mathbf{z}, t\mathbf{q}_n) = tc(\mathbf{z}, \mathbf{q}_n)$, implying:

$$a_0 + \sum_{m=1}^{5} a_m tq_{nm} + \sum_{k=1}^{K} b_k z_k + 0.5 \sum_{m=1}^{5}\sum_{p=1}^{5} a_{mp}t^2 q_{nm}q_{np} + 0.5 \sum_{k=1}^{K}\sum_{j=1}^{K} b_{kj}z_k z_j + \sum_{m=1}^{5}\sum_{k=1}^{K} c_{mk}tq_{nm}z_k$$

$$= ta_0 + \sum_{m=1}^{5} a_m tq_{nm} + \sum_{k=1}^{K} b_k tz_k + 0.5 \sum_{m=1}^{5}\sum_{p=1}^{5} a_{mp}tq_{nm}q_{np} + 0.5 \sum_{k=1}^{K}\sum_{j=1}^{K} b_{kj}tz_k z_j + \sum_{m=1}^{5}\sum_{k=1}^{K} c_{mk}tq_{nm}z_k$$

or $$a_0 + \sum_{k=1}^{K} b_k z_k + 0.5 \sum_{m=1}^{5}\sum_{p=1}^{5} a_{mp}t^2 q_{nm}q_{np} + 0.5 \sum_{k=1}^{K}\sum_{j=1}^{K} b_{kj}z_k z_j$$

$$= ta_0 + \sum_{k=1}^{K} b_k tz_k + 0.5 \sum_{m=1}^{5}\sum_{p=1}^{5} a_{mp}tq_{nm}q_{np} + 0.5 \sum_{k=1}^{K}\sum_{j=1}^{K} b_{kj}tz_k z_j$$

Thus, the technology will exhibit constant returns to scale if $a_0 = 0$, $b_k = 0$ for all k, $a_{mp} = 0$ for all m and p, and $b_{kj} = 0$ for all k and j. Under these restrictions equation (11) becomes

(12) $$\partial c(\mathbf{z}, \mathbf{q}_n)/\partial q_{nj} = a_j + \sum_{k=1}^{K} c_{jk}z_k$$

and equation (10) becomes

(13) $$m_j = a_j + \sum_{k=1}^{K} c_{jk}z_k - Q_j\eta_j^{-1}\bar{\theta}_{qjj} + \sum_{m=1}^{5} Q_m\varepsilon_{jm}^{-1}\bar{\theta}_{xjm}$$

or, using the result that $\varepsilon_{jm}^{-1} = b_{jm}/w_m$,

(14) $$m_j = a_j + \sum_{k=1}^{K} c_{jk}z_k + \beta_j Q_j + \sum_{m=1}^{5} \gamma_{jm}Q_m/w_m \qquad j = 1, \ldots, 5$$

where $\beta_j = -\eta_j^{-1}\bar{\theta}_{qjj}$ and $\gamma_{jm} = b_{jm}\bar{\theta}_{xjm}$. Equation (14) is the industry marketing margin equation expressing the retail and/or processing margin as a linear function of the prices of retailing and/or processing inputs and the quantities of dairy inputs/outputs. Note that the terms involving quantities represent deviations from the usual first order conditions obtained in perfectly competitive markets, and that these terms disappear if the average conjectural elasticities are equal to zero (perfect competition in input and output markets). Finally, economic theory tells us that $\eta_j \leq 0$, $\varepsilon_{jj} \geq 0$, $0 \leq \bar{\theta}_{qjm} \leq 1$ and $0 \leq \bar{\theta}_{xjm} \leq 1$ for all j and m. If, in addition, it is assumed that all inputs are normal (ie. an increase in output gives rise to a nonnegative change in the usage of each input) then the parameters must satisfy

$$\text{(15)} \qquad \beta_j \geq 0,\ \gamma_{jj} \geq 0 \text{ and } c_{jk} \geq 0 \qquad j = 1, \ldots, 5;\ k=1, \ldots, K.$$

Among other things, these restrictions imply that increases in the prices of inputs will give rise to nonnegative changes in marketing margins.

2.2. Market Milk Price Regulation at the Farm-Processor Point of Exchange

If the price of market milk at the farm-processor point of exchange is set by a regulatory authority then w_1 can be regarded as fixed and exogenous, $\partial w_1/\partial q_{nj} = 0$, and the first order conditions for profit maximisation, given by equation (8), become

$$\text{(16)} \qquad m_j + (\partial p_j/\partial q_{nj})q_{nj} - \sum_{m=2}^{5} (\partial w_2/\partial q_{nj})q_{nm} - \partial c(\mathbf{z}, \mathbf{q}_n)/\partial q_{nj} = 0 \qquad j = 1, \ldots, 5$$

Thus, the margins equations eventually become

$$\text{(17)} \qquad m_j = a_j + \sum_{k=1}^{K} c_{jk}z_k + \beta_j Q_j + \sum_{m=2}^{5} \gamma_{jm}Q_m/w_m \qquad j = 1, \ldots, 5$$

where the parameters satisfy the restrictions

$$\text{(18)} \qquad \beta_j \geq 0 \text{ and } c_{jk} \geq 0 \text{ for } j = 1, \ldots, 5 \text{ and } k = 1, \ldots, K; \text{ and } \gamma_{jj} \geq 0 \text{ for } j = 2, \ldots, 5.$$

Production quotas on the amount of market milk farmers can produce are assumed not to impact upon the amount of market milk processors will use as an input into the production process, other than through price effects.

3. ESTIMATION METHODS

In deregulated markets the margins equations are given by (14), and the parameters satisfy the restrictions given by (15). In markets where there is market milk price regulation at the processor-farmgate point of exchange, marketing margins are given by (17) and the parameters satisfy the restrictions given by (18). Empirical versions of these equations can be written compactly as

$$(19) \qquad m_{jt} = a_j + \sum_{k=1}^{K} c_{jk} z_{kt} + \beta_j Q_{jt} + \gamma_{j1} D_t Q_{1t}/w_{1t} + \sum_{m=2}^{5} \gamma_{jm} Q_{mt}/w_{mt} + v_{jt} \qquad j = 1, \ldots, 5$$

where the v_{jt} are normal random variables with zero means and constant variances σ_{vj}^2, D_t is a dummy variable which takes the value 1 when there is no market milk price regulation and 0 otherwise, and the parameters satisfy the restrictions given by (15).

Retail-farmgate and processor-farmgate margins equations for carton milk and WMP were estimated as an SUR system. Lack of data prevented the estimation of both types of margins equations for other products. Instead it was only possible to estimate retail-farmgate margins equations for butter and cheese, and only processor-farmgate margins for SMP. These margins equations were estimated as single equation models. In all cases non-linear least squares (NLS) was used to impose the restrictions given by (15).

4. DATA

The data consists of quarterly observations on farmgate prices and outputs of manufacturing and market milk, and the ex-processor and/or retail prices and quantities of five milk products (carton milk, WMP, butter, cheese and SMP) in six Australian states for the period 1986(1) to 1997(4). The data set is an extended and updated version of the data set used by O'Donnell and Coelli. Several observations are missing on the prices or quantities of particular milk products. Thus, only 213 observations were available to estimate carton-milk margins equations, 133 observations were available to estimate WMP margins equations, 264 observations were available to estimate butter and cheese equations, and 159 observations were available to estimate the SMP margins equation.

The measurement of margins for manufacturing milk products was problematic for three reasons. First, all four manufacturing milk products (WMP, butter, cheese and SMP) are joint products, implying that the single price paid for manufacturing milk is an aggregate of unobserved prices paid for the different 'components' of manufacturing milk which can be used to produce different products (eg. solids non-fat, buttermilk). Second, it is possible to produce different amounts of different products using the same fixed amount of manufacturing milk. For example, a fixed amount of manufacturing milk can be used to produce SMP, butter and butter-milk powder (BMP); or it can be used to produce WMP, butter and BMP; or it can be used to produce cheese, butter, BMP, and whey powder. Finally, differences in milkfat and protein percentages mean that these mixes of joint outputs can vary from state to state (a summary of product yields across states, for three common output mixes, is presented in Table 1).

In order to measure margins for the different milk products which can be obtained from the same physical quantity of manufacturing milk, the manufacturing milk price is broken down into the prices paid for the different components of manufacturing milk used to produce them. We undertake this decomposition using two alternative methodologies: a deterministic methodology involving the solution to a set of simultaneous equations, and a stochastic methodology involving non-linear regression analysis.

Simultaneous Equations Approach

The simultaneous equations approach suggests that approximately 85% of the observed manufacturing milk price in NSW can be regarded as being payment for the components of manufacturing milk which can be used to produce SMP, and approximately 18% is regarded as being payment for those components which can be used to produce butter. These numbers add up to more than one because processors appear to receive an amount equal to approximately 11% of the manufacturing milk price in return for accepting nuisance components used for the production of buttermilk powder (BMP). Of course, the manufacturing milk price also reflects payments for components which can be used to produce WMP, cheese and whey powder.

This apportionment of the manufacturing milk price between various components is based on the figures appearing in Table 1. Specifically, we assume that observed manufacturing milk prices are simply weighted averages of the unobserved ‘component prices’, where the weights are given by the component quantities. Then the figures in Table 1 can be used to obtain equations of the form:

NSW manuf. milk price = [882(NSW SMP component price)
+ 480(NSW butter component price)
+ 48(NSW BMP component price)] / (882+480+48)

NSW manuf. milk price = [1257(NSW WMP component price)
+ 89(NSW butter component price)
+ 9(NSW BMP component price)] / (1257+89+9)

and so on, across states and output mixes, yielding a set of 18 equations in 36 unknown component prices (six components by six states). It is assumed that all component prices are identical in NSW and Victoria, and that prices for the components used in the production of BMP, SMP and whey powder are equal across all states, leaving a set of 18 equations in 18 unknowns. Solving these equations for the unknowns makes it possible to express the prices of the different components in each state as functions of the manufacturing milk prices in *all* states (the full set of equations and the precise method of solution are available in a Technical Appendix available on request). Thus, for example, the average manufacturing milk prices in each state can be used to find the average NSW component price for SMP. Expressing this average NSW component price for SMP as a proportion of the average NSW manufacturing milk price yields 0.85147 (or approximately 85%). By way of further example, expressing the average NSW component price for butter as a proportion of the average NSW manufacturing milk price yields 0.17518 (or approximately 18%).

These average proportions were used to generate component prices in different states and time periods, and these component prices are regarded as the farmgate prices of manufacturing milk products. The average proportions differ by state and by product and are reported in Table 2.

Regression Approach

In the regression approach we assume

(20) $w_j = \alpha_j \times$ (the price of manufacturing milk)

where the α_j are unknown parameters to be estimated. We simply substitute (20) into (19) and rearrange the result to leave the output price as the dependent variable. Non-linear least squares is then used to estimate the seemingly unrelated regression (SUR) system of seven equations describing the prices of five products at up to two points of exchange. The parameters are estimated subject to the restrictions (15) and the additional restrictions $0 \leq \alpha_j \leq 1$ and $\sum_{j=2}^{5} \alpha_j = 1$. The pattern of missing prices and quantities in the data set means that only 104 observations are available to estimate the system. Using this methodology we estimate that 56% of the observed manufacturing milk price can be regarded as being payment for those components which can be used to produce SMP, approximately 38% can be regarded as being payment for components used to produce cheese, and approximately 6% can be regarded as payment for components used to produce WMP.

Irrespective of whether the simultaneous equations method or the regression method is used to break down the manufacturing milk price, the application of our estimated percentages to observed farmgate manufacturing milk prices yields farmgate prices for manufacturing milk products on a cents/litre basis (because the manufacturing milk price is measured in cents/litre, and the application of these percentages simply apportions this price between different products). However, it is convenient to measure margins for manufacturing milk products in terms of cents/kg rather than cents/litre. For WMP this means multiplying the cents/litre price by 10/1.25 (because 10 litres are needed to produce approximately 1.25 kg), for cheese it means multiplying the cents/litre price by 10, and for SMP it means multiplying the cents/litre price by 10/0.88. In the case of butter there are three output mixes which yield different quantities of butter so the cents/litre price is multiplied by 30/(0.5+0.11+0.05) (using the average).

Reported retail prices of manufacturing milk products are converted to a cents/kg basis by dividing the WMP retail price by 0.75 and dividing the butter and cheese retail prices by 0.5. All quantities are left in their original units (tonnes or kg): note from the form of the estimating equations that multiplying or dividing quantities by 1000 will simply have the effect of increasing or decreasing the order of the coefficients of the quantity variables by 1000.

5. RESULTS

All results were generated using SHAZAM (White, 1997). Our estimation methods ensure that all estimated coefficients are correctly signed. Thus, our discussion of the empirical results is mainly limited to the statistical significance of the estimated coefficients and the implications this may have for the capacity of different market agents to exert market power.

Estimates of the coefficients of the carton milk retail to farmgate margins equation are presented in Table 3. The two columns in Table 3 are the estimates obtained when the simultaneous equations method (Model A) and the regression method (Model B) are used to apportion the manufacturing milk price. There are several implications to be drawn from Table 3. First, our estimate of β_1 is significantly different from zero[1], implying carton milk retailers possess market power in the sale of market milk to consumers. If the slope of the consumer demand function for carton milk at the retail level is, for example, -0.5 then our estimate of β_1 implies that $\bar{\theta}_{q11}$, the conjectural elasticity which measures the percentage change in aggregate output in response to a one-percentage change in the output of an individual firm, is approximately 0.01. Second, our estimate of γ_{11} is also significantly different from zero, with the implication that, in deregulated markets, carton milk processors possess market power in the purchase of market milk from farmers. Third, materials and transport prices have a statistically significant impact on the size of the carton milk retail to farmgate margin, but labour prices do not. Interestingly, the estimated labour price coefficient is exactly zero, with estimated standard error exactly zero. This is a direct consequence of the sampling theory approach to imposing inequality constraints: when the constraint is binding, parameter estimates are placed exactly on the inequality boundary. Fourth, after accounting for all other price and quantity effects, the margin appears to be significantly greater in the March and June quarters, by approximately 2 cents/litre/quarter.

[1] The usual t statistic is asymptotically standard normal even though the parameter is inequality constrained and the null hypothesis places it at the inequality boundary. See Gourieroux *et al* (1982).

Finally, the similarity between our Model A and Model B results suggests that these conclusions are robust to the method of apportioning the manufacturing milk price between different outputs.

Estimates of the coefficients of the carton milk processor to farmgate margins equation are presented in Table 4. Again, our estimates of β_1 and γ_{11} are significantly different from zero, suggesting that carton-milk processors possess market power in both output and (deregulated) input markets. These results are consistent with the results presented in Table 3. The estimates also suggest that labour, materials and transport prices all have a statistically significant impact on the processor-farmgate margin. Finally, after accounting for all input price and quantity effects, it appears that processor to farmgate carton milk margins are higher in the December, March and June quarters, and have been increasing over time at the low rate of approximately 0.06 cents/litre per annum.

Estimates of the coefficients of the WMP retail to farmgate margins equation are presented in Table 5. It is evident from this table that WMP retailers possess no market power in the sale of WMP to consumers (our Model A and Model B estimates of β_2 are exactly zero), nor do WMP processors possess market power in the purchase of manufacturing milk from farmers (our Model A and Model B estimates of γ_{22} are not significantly different from zero). The estimates suggest that, after accounting for all input price and quantity effects, the WMP retail to farmgate margin has been falling at a rate of approximately 2 or 3 cents/kg per annum.

Results for the WMP processor to farmgate margins equation are presented in Table 6. Our Model A and Model B estimates of γ_{22} are not significantly different from zero, confirming that WMP processors possess no market power in the purchase of manufacturing milk from farmers. Our estimates of β_2 also suggest that WMP processors possess no market power in the sale of WMP to retailers. Finally, in line with the decline over time in the retail to farmgate WMP margin, the processor to farmgate WMP margin has been shrinking at a rate of approximately 2 cents/kg per annum.

Results from estimating the butter retail to farmgate margin are reported in Table 7. Our estimates of β_3 are exactly zero, implying butter retailers have no market power in the sale of butter to consumers. However, our estimates of γ_{33} are statistically significant, suggesting that butter processors have market power in the purchase of manufacturing milk from farmers. Materials, labour and transport prices appear not to have any significant impact on the margin. There is some evidence that butter margins increase with increases in the production of carton milk and decreases in the production of cheese and SMP, reflecting the nature of the joint production technology. After accounting for all input price and quantity effects, the butter retail to farmgate margin has been decreasing over time, at a rate of approximately 3.3 cents/kg per annum.

Estimates of the coefficients of the cheese retail to farmgate margins equation are presented in Table 8. Cheese retailers and processors appear to have no market power in either the sale of cheese to consumers or the purchase of manufacturing milk from farmers. There appear to be no price or quantity variables influencing cheese retail to farmgate margins. The only variable influencing the margin appears to be the passage of time: cheese margins appear to be increasing at a rate of approximately 0.5 cents/kg per annum.

Our final set of estimates are for SMP processor to farmgate margins, and these are presented in Table 9. Again, SMP processors appear to have no market power in either input or output markets. Moreover, there is evidence that SMP margins vary with variations in the production levels of carton milk, butter and cheese, confirming the joint product relationships identified in Table 7. Finally, after all price and quantity effects are accounted for, SMP margins appear to have been increasing over time, at a rate of somewhere between 1 and 2 cents/kg per annum.

6. CONCLUSION

We have used economic theory to derive a set of industry marketing margins equations for five dairy products (carton milk, whole-milk powder, butter, cheese and skim-milk powder) at the retail and processor levels. Our theoretical model permits conjectural elasticities in input and output markets to differ, and allows for multiple outputs to be produced using a single agricultural input. Lack of data on some retail and ex-processor prices has prevented the estimation of retail-farmgate and processor-farmgate margins for some products. Many of the estimated coefficients were constrained to possess the signs implied by economic theory, and all coefficients have good statistical properties.

The results suggest that, in price-deregulated markets, carton milk retailers and processors possess market power in the sale of carton milk, and carton milk processors possess market power in the purchase of market milk from farmers. Butter processors also appear to possess market power in the purchase of manufacturing milk. It appears that no other market intermediaries possess market power in either input or output markets.

The usefulness of our empirical results is limited by our inability to separately identify the slopes of our input demand and output supply functions, and therefore the conjectural elasticities. The identification of these quantities is possible only by including these functions in an extended empirical model. It is also possible to extend the theoretical model by considering alternative and possibly more general functional forms, although this may result in nonlinear margins equations which may be difficult to estimate. Assuming a normalised quadratic input supply or output demand function, for example, will result in margins equations which are highly nonlinear and where functions of the parameters must satisfy highly nonlinear inequality constraints. The sampling theory approach we have used to impose inequality constraints in this paper has the drawback that if the constraints are binding then our estimates necessarily take values on the inequality boundary (ie. at zero), and this is inefficient because it ignores sample information away from the boundary. Future research might focus on overcoming this drawback by estimating the model within a Bayesian framework.

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Table 1

Product Yields (kg) from 10,000 litres of Manufacturing Milk, by State.

Mix	Product	NSW	VIC	QLD	SA	WA	TAS
Output	SMP	882	880	877	881	869	881
Mix	Butter	480	507	471	488	476	529
1	BMP	48	51	47	49	48	53
Output	WMP	1257	1254	1251	1256	1238	1256
Mix	Butter	89	117	82	98	91	139
2	BMP	9	12	8	10	9	14
Output	Cheddar	998	1002	979	999	950	1015
Mix	Butter	31	56	31	39	49	72
3	BMP	3	6	3	4	5	7
	Whey Powder	624	620	626	623	625	617

Table 2

Average Proportions of the Manufacturing Milk Price Paid in Respect of Manufacturing Milk Components

	NSW	VIC	QLD	SA	WA	TAS
SMP	0.851	0.846	0.970	0.939	1.014	0.933
Butter	0.175	0.197	0.138	0.157	0.135	0.184
BMP	-0.113	-0.129	-0.126	-0.131	-0.144	-0.153
WMP	0.972	0.964	0.993	0.988	1.001	0.982
Cheese	0.384	0.385	0.300	0.327	0.263	0.330
Whey Powder	0.607	0.602	0.698	0.670	0.694	0.661

Table 3

Parameter Estimates: Carton Milk Retail to Farmgate Margin[a]

Coefficient	Variable	Model A	Model B
a_1	Constant	-92.098 (15.642)	-93.430 (15.513)
c_{11}	December quarter dummy	1.311 (0.798)	1.260 (0.786)
c_{12}	March quarter dummy	1.904 (0.783)	2.002 (0.758)
c_{13}	June quarter dummy	2.296 (0.747)	2.415 (0.757)
c_{14}	Time trend	0.022 (0.035)	0.015 (0.034)
c_{15}	Materials Price	0.570 (0.070)	0.564 (0.067)
c_{16}	Labour Price	0.000 (0.000)	0.000 (0.000)
c_{17}	Transport Price	0.816 (0.145)	0.830 (0.144)
β_1	Q_{1t} - carton milk	0.022 (0.006)	0.025 (0.006)
γ_{11}	D_tQ_{1t}/w_{1t} - dereg. carton milk	4.392 (0.446)	4.402 (0.511)
γ_{12}	Q_{2t}/w_{2t} - WMP	0.067 (0.019)	0.004 (0.001)
γ_{13}	Q_{3t}/w_{3t} - butter	-0.055 (0.037)	-0.000 (0.000)
γ_{14}	Q_{4t}/w_{4t} - cheese	-0.023 (0.007)	-0.023 (0.007)
γ_{15}	Q_{5t}/w_{5t} - SMP	0.043 (0.026)	0.033 (0.018)

[a] Numbers in parentheses are estimated standard errors.

Table 4

Parameter Estimates: Carton Milk Processor to Farmgate Margin[a]

Coefficient	Variable	Model A	Model B
a_1	Constant	-105.750 (12.704)	-107.640 (13.355)
c_{11}	December quarter dummy	1.911 (0.652)	1.844 (0.635)
c_{12}	March quarter dummy	2.120 (0.633)	2.190 (0.621)
c_{13}	June quarter dummy	2.108 (0.608)	2.220 (0.605)
c_{14}	Time trend	0.066 (0.030)	0.058 (0.029)
c_{15}	Materials Price	0.353 (0.057)	0.345 (0.057)
c_{16}	Labour Price	0.372 (0.048)	0.380 (0.046)
c_{17}	Transport Price	0.505 (0.112)	0.516 (0.121)
β_1	Q_{1t} - carton milk	0.016 (0.005)	0.020 (0.005)
γ_{11}	D_tQ_{1t}/w_{1t} - dereg. carton milk	3.348 (0.371)	3.397 (0.412)
γ_{12}	Q_{2t}/w_{2t} - WMP	0.039 (0.016)	0.002 (0.001)
γ_{13}	Q_{3t}/w_{3t} - butter	-0.095 (0.029)	-0.000 (0.000)
γ_{14}	Q_{4t}/w_{4t} - cheese	-0.027 (0.005)	-0.026 (0.006)
γ_{15}	Q_{5t}/w_{5t} - SMP	0.075 (0.021)	0.051 (0.014)

[a] Numbers in parentheses are estimated standard errors.

Table 5

Parameter Estimates: WMP Retail to Farmgate Margin[a]

Coefficient	Variable	Model A	Model B
a_2	Constant	463.260 (16.826)	646.840 (14.721)
c_{21}	December quarter dummy	7.712 (9.869)	8.249 (8.546)
c_{22}	March quarter dummy	-2.977 (9.394)	-2.986 (7.968)
c_{23}	June quarter dummy	7.540 (9.349)	9.215 (7.836)
c_{24}	Time trend	-2.494 (0.508)	-3.325 (0.428)
c_{25}	Materials Price	0.000 (0.000)	0.000 (0.000)
c_{26}	Labour Price	0.000 (0.000)	0.000 (0.000)
c_{27}	Transport Price	0.000 (0.000)	0.000 (0.000)
β_2	Q_{2t} - WMP	0.000 (0.000)	0.000 (0.000)
γ_{21}	D_tQ_{1t}/w_{1t} - dereg. carton milk	13.531 (5.028)	9.479 (4.616)
γ_{22}	Q_{2t}/w_{2t} - WMP	0.061 (0.224)	0.012 (0.011)
γ_{23}	Q_{3t}/w_{3t} - butter	0.278 (0.505)	0.000 (0.000)
γ_{24}	Q_{4t}/w_{4t} - cheese	-0.130 (0.095)	-0.152 (0.085)
γ_{25}	Q_{5t}/w_{5t} - SMP	-0.071 (0.321)	-0.047 (0.195)

[a] Numbers in parentheses are estimated standard errors.

Table 6

Parameter Estimates: WMP Processor to Farmgate Margin[a]

Coefficient	Variable	Model A	Model B
a_2	Constant	164.610 (32.752)	337.460 (34.814)
c_{21}	December quarter dummy	-6.924 (20.773)	-6.709 (21.324)
c_{22}	March quarter dummy	23.002 (19.395)	23.587 (20.929)
c_{23}	June quarter dummy	-14.898 (19.576)	-12.517 (20.828)
c_{24}	Time trend	-1.183 (0.960)	-1.892 (0.994)
c_{25}	Materials Price	0.000 (0.000)	0.000 (0.000)
c_{26}	Labour Price	0.000 (0.000)	0.000 (0.000)
c_{27}	Transport Price	0.000 (0.000)	0.000 (0.000)
β_2	Q_{2t} - WMP	0.000 (0.000)	0.001 (0.009)
γ_{21}	D_tQ_{1t}/w_{1t} - dereg. carton milk	-2.643 (10.601)	-9.388 (11.484)
γ_{22}	Q_{2t}/w_{2t} - WMP	0.332 (0.453)	0.015 (0.088)
γ_{23}	Q_{3t}/w_{3t} - butter	-0.516 (0.933)	-0.000 (0.000)
γ_{24}	Q_{4t}/w_{4t} - cheese	-0.313 (0.171)	-0.187 (0.187)
γ_{25}	Q_{5t}/w_{5t} - SMP	0.551 (0.602)	0.372 (0.482)

[a] Numbers in parentheses are estimated standard errors.

Table 7

Parameter Estimates: Butter Retail to Farmgate Margin[a]

Coefficient	Variable	Model A	Model B
a_3	Constant	232.630 (47.844)	384.870 (58.990)
c_{31}	December quarter dummy	6.731 (5.532)	-3.424 (5.132)
c_{32}	March quarter dummy	1.675 (5.311)	-3.827 (4.949)
c_{33}	June quarter dummy	-2.436 (4.962)	-3.156 (4.836)
c_{34}	Time trend	-3.310 (0.256)	-3.125 (0.254)
c_{35}	Materials Price	0.397 (0.447)	0.334 (0.553)
c_{36}	Labour Price	0.000 (0.000)	0.000 (0.000)
c_{37}	Transport Price	0.000 (0.000)	0.000 (0.000)
β_3	Q_{3t} - butter	0.000 (0.000)	0.000 (0.000)
γ_{31}	D_tQ_{1t}/w_{1t} - dereg. carton milk	23.074 (3.741)	4.180 (3.244)
γ_{32}	Q_{2t}/w_{2t} - WMP	0.035 (0.168)	0.012 (0.010)
γ_{33}	Q_{3t}/w_{3t} - butter	0.853 (0.264)	0.000[b] (0.000)[c]
γ_{34}	Q_{4t}/w_{4t} - cheese	-0.264 (0.051)	-0.124 (0.054)
γ_{35}	Q_{5t}/w_{5t} - SMP	-0.323 (0.195)	-0.253 (0.120)

[a] Numbers in parentheses are estimated standard errors.
[b] Non-zero when rounded to 5 decimal places.
[c] Non-zero when rounded to 6 decimal places.

Table 8

Parameter Estimates: Cheese Retail to Farmgate Margin[a]

Coefficient	Variable	Model A	Model B
a_4	Constant	533.730 (6.628)	522.740 (6.446)
c_{41}	December quarter dummy	0.088 (6.729)	-0.836 (6.281)
c_{42}	March quarter dummy	2.501 (6.873)	3.111 (5.686)
c_{43}	June quarter dummy	-2.108 (6.218)	0.136 (6.262)
c_{44}	Time trend	0.531 (0.239)	0.592 (0.225)
c_{45}	Materials Price	0.000 (0.000)	0.000 (0.000)
c_{46}	Labour Price	0.000 (0.000)	0.000 (0.000)
c_{47}	Transport Price	0.000 (0.000)	0.000 (0.000)
β_4	Q_{4t} - cheese	0.000 (0.000)	0.000 (0.000)
γ_{41}	D_tQ_{1t}/w_{1t} - dereg. carton milk	1.881 (4.487)	-3.595 (4.123)
γ_{42}	Q_{2t}/w_{2t} - WMP	-0.287 (0.189)	-0.010 (0.011)
γ_{43}	Q_{3t}/w_{3t} - butter	0.102 (0.344)	-0.000 (0.000)
γ_{44}	Q_{4t}/w_{4t} - cheese	0.000 (0.000)	0.000 (0.000)
γ_{45}	Q_{5t}/w_{5t} - SMP	-0.042 (0.258)	0.042 (0.174)

[a] Numbers in parentheses are estimated standard errors.

Table 9

Parameter Estimates: SMP Processor to Farmgate Margin[a]

Coefficient	Variable	Model A	Model B
a_5	Constant	-70.991 (15.639)	37.289 (13.212)
c_{51}	December quarter dummy	-6.318 (9.904)	-2.276 (8.967)
c_{52}	March quarter dummy	17.293 (9.913)	16.399 (8.747)
c_{53}	June quarter dummy	4.864 (10.339)	2.585 (8.912)
c_{54}	Time trend	1.635 (0.456)	0.960 (0.387)
c_{55}	Materials Price	0.000 (0.000)	0.000 (0.000)
c_{56}	Labour Price	0.000 (0.000)	0.000 (0.000)
c_{57}	Transport Price	0.000 (0.000)	0.000 (0.000)
β_5	Q_{5t} - SMP	0.000 (0.000)	0.000 (0.002)
γ_{51}	D_tQ_{1t}/w_{1t} - dereg. carton milk	-11.499 (5.472)	-4.774 (4.830)
γ_{52}	Q_{2t}/w_{2t} - WMP	-0.282 (0.269)	-0.016 (0.014)
γ_{53}	Q_{3t}/w_{3t} - butter	-1.291 (0.505)	-0.000 (0.000)
γ_{54}	Q_{4t}/w_{4t} - cheese	0.306 (0.098)	0.214 (0.087)
γ_{55}	Q_{5t}/w_{5t} - SMP	0.590 (0.321)	0.299 (0.330)

[a] Numbers in parentheses are estimated standard errors.