A SPATIAL EQUILIBRIUM MODEL OF THE EASTERN AUSTRALIAN DAIRY INDUSTRY

by

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The purpose in this research is to assess the implication that changes in the dairy marketing arrangements will have on in trade in dairy products in Australia. Central to this research is the construction of a spatial equilibrium model of the dairy market. The result of a preliminary specification of the model is presented, which contains a number of restrictive assumptions. Despite this, the model predicts actual production and consumption levels, prices and trade flows reasonably well. The model will ultimately be used to predict the outcome of liberalising interstate trade in market milk.

1. Introduction

The trend in agricultural policy in Australia is toward the deregulation and rationalisation of production and marketing. This is evident in the dairy industry which has adjusted rapidly over recent decades. While adjustments have been made in the liquid milk segment of the industry, the most dramatic changes have occurred in the sectors related to producing and processing of milk for manufactured dairy products. The regulation of liquid milk supplies and interstate movements of 'market milk', remains a contentious issue, particularly among those in the industry in New South Wales and Victoria.

A spatial equilibrium model of the Eastern Australian mainland states dairy industry is being developed which will be used to assess the implications of changes in dairy marketing arrangements. Of particular interest are the changes that may occur to the system of producing and distributing liquid milk. The modelling effort to date has been directed towards estimating the demand schedules for butter, cheese and market milk in New South Wales, Queensland and Victoria, along with specifying the transport and processing links in the dairy industry. Many of the issues to be dealt with in this project are presented in Davidson, MacAulay and Powell, (1989a). In this paper, a preliminary model of the eastern Australian mainland states dairy industry is presented. This model will ultimately be used to assess the impacts of a more liberalised trade in market milk. From such an analysis it should be possible to indicate

[1]Research on this project was supported by the Dairy Research Council.

production and consumption trends, prevailing market prices and trade flows in each of the state dairy markets in question. These can provide information for consideration of the efficiency and equity effects on those involved.

2. A Model of the Dairy Industry

The purpose in this section is to outline the general model utilised in this study. The framework chosen to analyse the Australian dairy industry is the spatial equilibrium model. The theoretical specification of the spatial equilibrium model is not detailed here, but can be obtained from Takayama and Judge 1971. This technique has the advantage of explicitly characterising the trade and price linkages between regions. Thus, the seasonal and cyclical patterns in the industry can be identified according to the regions in which they occur. To date, most studies of the dairy market have used econometric models, such as Lembit and Hall (1987) and Coelli and Battese (1987), while only two (Mackay 1975 and Blyth 1984) have used a mathematical programming model of the spatial equilibrium type. However, both Mackay and Blyth only analysed the New South Wales industry.

A comparative static analysis of the dairy industry provides the initial basis for constructing a model of the industry. Spatial equilibrium theory relates to the flow of goods between geographically dispersed markets. These markets are separated, but not isolated by the costs of transferring a commodity between the markets. Four key assumptions of the basic model can be identified:

- to simplify the computation, the production and consumption of the commodity is assumed to take place at a single location in each market;
- transfer costs are given and are independent of the volume of trade (such an assumption rules out the possibility of transport companies having different rates depending on the competitiveness on each route and the bulkiness of cargo);
- perfect competition exists in each market and thus, all traders attempt to maximise profits and have perfect knowledge of all factors influencing the market; and
- the demand and supply functions for each market are known (Tomek and Robinson 1982).

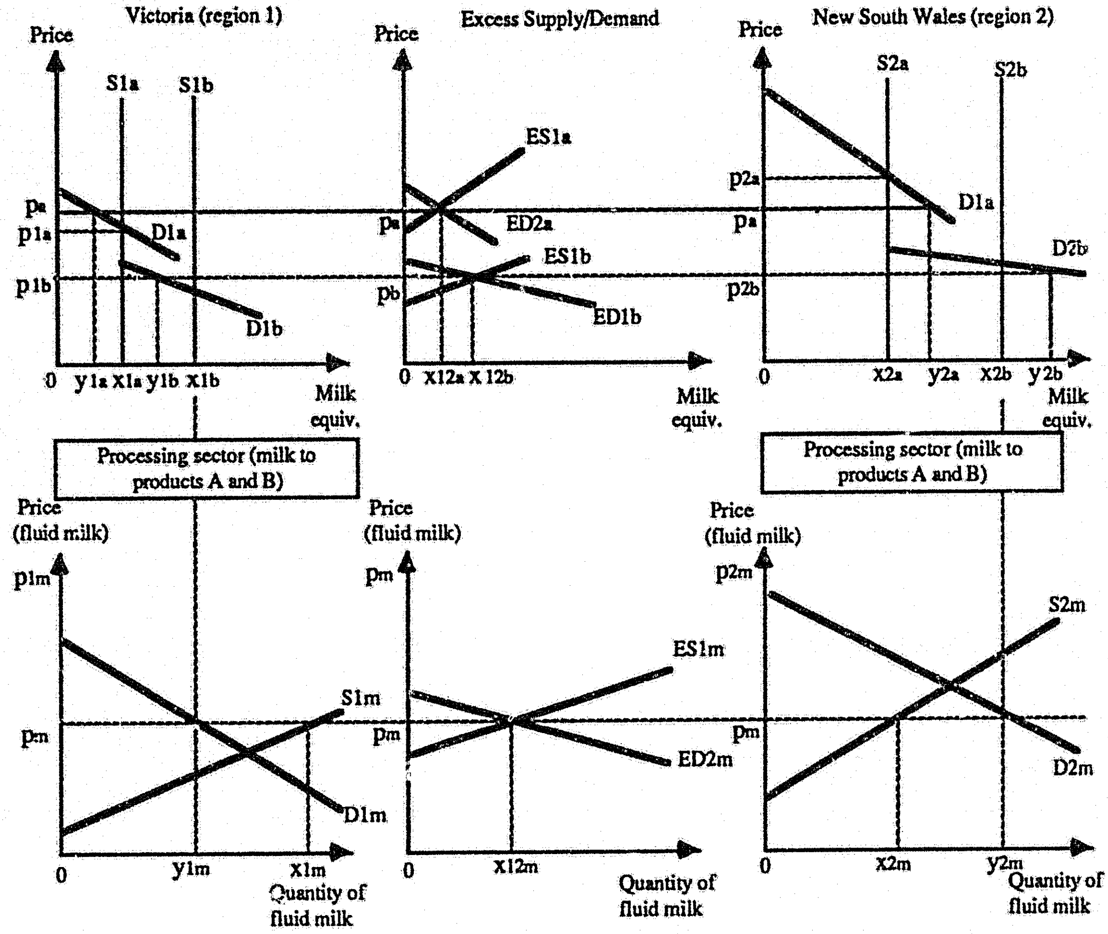
Although clearly restrictive, some of these assumptions can be relaxed. In addition to these four assumptions, it will initially be assumed that there are only two regions, New South Wales (an importing region) and Victoria (an exporting region). Further, it is assumed that only two products are processed and consumed from whole milk (market milk and manufactured products) and that these products are fixed in proportion (that is, 50 per cent market milk and 50 per cent manufactured products from a given quantity of liquid milk) and no wastage is involved. To simplify matters, it can be assumed that transport costs are equal to zero although these could readily be included. Finally, it is assumed that the supply and demand schedules for whole milk and its processed products are linear and fixed in the short run. Hence, for this analysis it is implicitly assumed that the industry is static, the quantity of farm milk supplied to processors is fixed and is inelastic at the processing level.

In Figure 1 a diagrammatic representation of the dairy industry is presented in which the following supply and demand relationships can be identified;

- D1m is the derived demand for liquid milk in Victoria;
- D2m is the derived demand for liquid milk in New South Wales;
- S1m is the supply of liquid milk in Victoria;
- S2m is the supply of liquid milk in New South Wales;
- D1a is the demand for market milk in Victoria;
- D1b is the demand for manufactured milk in Victoria;
- D2a is the demand for market milk in New South Wales;
- D2b is the demand for manufactured milk in New South Wales;
- S1a is the derived supply of market milk in Victoria;
- S1b is the derived supply of manufactured milk in Victoria;
- S2a is the derived supply of market milk in New South Wales; and
- S2b is the derived supply of manufactured milk in New South Wales.

Two scenarios are of interest in this study; the current situation in which there is no trade in market milk and that in which trade is allowed. Under current dairy industry policy, trade is permissible in whole milk at the farm level and in manufactured dairy products. At the farm level the cost of producing milk in Victoria is less than it is in New South Wales. Consequently, Victoria (region 1) can potentially export milk to New South Wales (region 2), the quantity being determined by the interaction of the excess supply and excess demand for whole milk ($ES1_m$ and $ED2_m$ respectively). At the prevailing price (p_m) whole milk trade ($0x_{12m}$) equals the quantity exported from Victoria ($x_{1m} - y_{1m}$) which equals the quantity imported by New South Wales ($y_{2m} - x_{2m}$). Given the assumption that there is no wastage in the system, then the amounts $0y_{1m}$ and $0y_{2m}$) of whole milk are supplied to the processing sectors in Victoria and New South Wales, respectively.

The processing sector supply schedules are perfectly inelastic in this analysis. Due to the assumption of fixed output proportions from the processing sector, whole milk supply can be separated equally into that destined for use as market milk (S_{1a} and



Note: yi refers to a demand quantity, xi refers to a supply quantity and xij refers to a trade flow where i and j are numerals.

Figure 1: Schematic Diagram of the Dairy Industry.

S2b) in Victoria and New South Wales, respectively. Consequently $0x_{1a}$ and $0x_{2a}$ of market milk is processed in Victoria and New South Wales, respectively, while $x_{1a}x_{1b}$ and $x_{2a}x_{2b}$ of manufactured dairy products (in milk equivalent terms) are produced in each state.

In Figure 1, the demand curves for manufactured dairy products are represented in an unusual form. While the demand curves for market milk commence at the vertical axis and are downward sloping in the positive quadrant, the demand curves for manufactured products are horizontally shifted to the right and commence at the level of production of market milk. This transformation results in the whole analysis being represented on a single diagram. The quantity of market milk consumed in Victoria and New South Wales (x_{1a} and x_{2a}, respectively) equals the quantities processed since trade between states is not permitted.[1] The price of market milk is determined by the intersection of the demand and supply for the product in each state p_{1a} and p_{2a}. Given that interstate trade in market milk is not possible, the price in New South Wales is higher than in Victoria. With trade possible in manufactured products, an equilibrium price p_b, rules in both markets. In Victoria, $x_{1a}y_{1b}$ of manufactured products are consumed domestically, while the remaining production $y_{1b}x_{1b}$ is exported to New South Wales. Similarly, all of the manufactured products that are produced in New South Wales ($x_{1a}x_{1b}$) are consumed, along with that imported from Victoria ($x_{1b}y_{1b}$). To have a fully equilibrating system, the quantity of manufactured products traded $0x_{12b}$, must equal the quantity exported from Victoria $y_{1b}x_{1b}$, which in turn must equal the quantity imported into New South Wales $x_{2b}y_{2b}$, at the prevailing price p_b.

If trade in market milk is permitted then an equilibrium price (p_a) is established by the intersection of the excess supply and excess demand schedules for market milk ($ES1_a$ and $ED1_a$ respectively). The construction of these curves is similar to those mentioned above, yet complicated by the way the diagram is drawn. The excess supply schedule ($ES1_a$) is the difference between the supply and demand schedules in the exporting regions ($S1_a$ and $D1_a$) and represents the extra amount of the commodity which can be produced and supplied by that market to another market at a given set of prices. Similarly, an excess demand schedule ($ED2_a$) can be constructed in the trade sector, which is the increased demand for the commodity by the importing region if trade were possible. The excess demand schedule is the difference between the commodities demand and supply schedules in the importing region ($D2_a$ and $S2_a$). The intersection of the excess supply and demand curves determines the world equilibrium trade point. The quantity $0x_{12a}$ of market milk will be traded, with $y_{1a}x_{1a}$ being exported from Victoria and $x_{2a}y_{2a}$ being imported into New South Wales. In Victoria less market milk is domestically consumed and prices rise from p_{1a} to p_a, while in New South Wales more is consumed and prices fall from p_{2a} to p_a.

In this section the framework upon which a dynamic model of the dairy industry can be constructed, has been outlined. The approach taken was to describe the framework in terms of a simple model. Given that a supply and demand curve must be estimated for each region, then producer's revenues and exports can be observed in the model described above. Consequently, the framework is a feasible modelling strategy for the industry as a whole. However, whether it can address the particular set of questions at hand, will depend on how closely the estimated model to be constructed can approximate the dairy industry in its present state. This question will be addressed in the next section.

3. Modelling Considerations

The purpose in this section is to disaggregate the model presented in the previous section into its various components. In undertaking this task a number of considerations need to be taken into account. These include the definition of the regions, the location of the supply and consumption points within each region, the number of products and market levels to be considered, the links between products and market levels and how government regulation can be imposed upon the model. Once these considerations have been addressed, the components requiring estimation can be identified.

Given the problem at hand, it is essential to estimate supply and demand schedules for New South Wales, Victoria and Queensland. In addition, trade is undertaken between these regions and the rest of Australia and the international market. Consequently, these two other regions can be identified as trade points within the model. Given the assumptions of the spatial equilibrium model, specific points within these regions must be identified in order to compile a schedule of transportation costs. For the sake of simplicity, production and consumption will be assumed to occur at the capital city in each region. In the case of the rest of Australia region, it will be assumed that all activity occurs in Adelaide, the largest population centre in the region, and closest to the greatest concentration of production. On the export market, it will be assumed that consumers pay the cost of freight. As a consequence, there is no reason to identify a trade point in the analysis as the freight rate is equal to zero.

Data are readily available on the quantity of market milk demanded in each region, along with the quantity of wholemilk supplied in New South Wales, Victoria and Queensland. However, this is not the case for butter and cheese demand in each region. Estimates of the demand for these two products can be derived on an annual basis. In addition exports from these three producing regions to the rest of Australia and the export markets during 1986-87 have been estimated by the Australian Dairy Corporation. Hence, it is possible to specify a balance sheet of production and consumption within the regions once the demand for butter and cheese have been converted to milk equivalent units. In other words after standardising the quantities of cheese and butter produced for their milk content, five dairy products can be identified:

- whole milk, which is unprocessed milk, and cannot be retailed;
- market milk;
- cheese (which only includes the product 'leviable' by the Australian Dairy Corporation);
- butter; and
- other, which accounts for the residual quantity of whole milk not being used in the production of either market milk, butter or cheese.

It must be noted that in calculating the balance sheet, it is assumed that there is no wastage in the processing system, that the milk equivalent factors are relevant for all milk production and that each product grouping is perfectly homogeneous within and perfectly heterogeneous between categories. The details of this balance sheet are presented in Appendix A.

In order to address the questions raised in this study it is necessary to estimate retail demand schedules for market milk, butter and cheese in New South Wales, Victoria and Queensland along with each region's whole milk supply schedule. Given the negligible quantities of butter and cheese imported into these three regions it will be assumed that the export and rest of Australia market are net importing regions with no production. Hence, they are characterised by a perfectly inelastic demand curve for both the export and the rest of Australia markets (that is, crossing the horizontal axis at the quantity demanded). In each market it is also assumed for the sake of simplicity that the residual products are consumed in the same region that they are produced and that market milk can only be traded within New South Wales, Queensland or Victoria; and not between the regions. The implication of these assumptions, from a modelling stance is that it is only necessary to specify supply curves for whole milk in New South Wales, Victoria and Queensland, demand curves for market milk, butter and cheese in these three regions and treat the demand for butter and cheese in the export and rest of Australia markets along with other products in all markets as exogenously predetermined.

Given that only two market levels are assessed in this study (farm and retail) and that there are only three regions in which production takes place and five regions in which demand takes place, it is necessary to specify the links between whole milk supply and dairy product demand. Within a region, the difference between whole milk supply and a particular product demand is equal to the cost of processing a unit of milk content (that is, the marketing margin). In the case of supply from one region being consumed in another, the cost of transporting the finished product between the regions is added to the marketing margin. While analysing the links between market levels in this manner considerably simplifies the task at hand (as there is no necessity to calculate derived demand curves for whole milk or derived supply schedules for dairy products) it imposes the assumption on the model that trade can only occur at the final product stage and that processing costs are fixed and do not change as the quantity processed changes.

Of interest in this study are those policies that relate to market milk and its non-tradable status. The method chosen to assess the impacts of this regulation is to impose constraints on the supply schedules in each state and to manipulate the freight rates between regions. As a consequence, it was assumed that the market milk sectors in New South Wales, Victoria and Queensland are segregated from the manufacturing milk sector. As production quotas exist in these regions, the market milk supply schedules are assumed to be perfectly inelastic. Furthermore, as the Victorian Dairy Industry Authority regulates the quantity of market milk processed, the demand schedule in this region can be treated in the same manner as the other two states (i.e. perfectly inelastic). In addition, as no trade is permitted, the transport rates between these market milk sectors and the rest of the model are set at artificially high levels. The results from this analysis should reflect the current situation.

In order to analyse a situation in which interstate trade is permitted, it is necessary to modify the artificially high transport rates to reflect the true costs of transferring market milk. If there is a need to analyse the situation in which the system of production quotas is abolished, then that component of the model which segments the market milk and manufacturing sectors of the market can be removed. In other words, the market milk supply schedules for New South Wales and Queensland are taken out of the model and the whole milk supply schedules in these two regions and recalculated to reflect the increased quantities supplied. While these situations are not modelled in this paper, it is necessary to make sure that the model can be adjusted to handle these possibilities.

In summary, it is necessary to specify the intercepts and slopes of the supply of whole milk and demand for market milk, butter and cheese in New South Wales, Queensland and Victoria. In addition, it is necessary to derive the cost of processing and transporting these products between the regions specified above, to the export market and rest of Australia market. The demand curves for butter and cheese in the rest of Australia market, along with the demand schedules for 'other' dairy products, and the export demand for butter and cheese are perfectly inelastic.

4. Data Requirements

From the previous section it is apparent that the estimation of the various components of the model will play a crucial role in determining the outcome of this study. Of interest is the estimation of whole milk supply schedule, along with the demand for various dairy products. Furthermore, it is necessary to specify the links between farm milk production and wholesale demand or the processing sector for each of the regions and the costs of transporting products between regions.

The most recent analysis of farm level milk supply has been undertaken by the Australian Bureau of Agricultural and Resource Economics (see Williamson, Lembit and Topp, 1987). They suggest that the long run own price elasticity of supply of whole milk in New South Wales, Victoria and Queensland is equal to 2.23, 1.71 and 1.12 respectively (Williamson, Australian Bureau of Agricultural and Resource Economics , personal communication 1/12/88). These elasticities, while long term in nature, appear to be too high to be credible Using these elasticities, along with the quantities actually produced and the prevailing farm level prices in 1986-87, the slopes and intercepts for whole milk supply can be derived (see Table 1).

There are few analysts who have estimated the demand for Australian dairy products. Most have either estimated the demand for a particular product, or have aggregated all products together. A different approach taken by Blyth (1984), was to estimate the demand for market milk separately from that of manufactured products. In this study it was necessary to obtain the demand for market milk, cheese and butter. The results of the econometric estimation of these functions are presented in Table 2 (for a more detailed discussion of these results see Davidson, MacAulay and Powell forthcoming) but they are disappointing. The basic problem with these results is the inadequacy of the data. Only 13 observations were available for analysis and no information could be gained on non-retail consumption. Even the consumer level consumption data accounted only for warehouse withdrawals, not actual sales. This implies that processing uses of products were not accounted for.

The own-price elasticities of demand derived from the estimation procedure are presented in Table 1, with the intercept and slope coefficients to be included in the spatial equilibrium model The estimated own-price elasticities of demand appear to be credible. The non-responsiveness of the quantity of market milk to a change in price is consistent with the view that the product is not only a necessity, but also vital to the health and well-being of consumers. The relatively inelastic nature of cheese demand is

Table 1

Supply and Demand Functions for Milk and Dairy Products

Item	Own-price Elasticity	Function
A. Wholemilk supply		
- New South Wales	2.23	$Q_{s,1} = -1114.380 + 35.227 P_{w1}$
- Victoria	1.71	$Q_{s,1} = 482.762 + 167.779 P_{w2}$
- Queensland	1.12	$Q_{s,3} = -729.953 + 49.794 P_{w3}$
B. Market milk demand		
- New South Wales	0.0	$Q_{d,m1} = 593.7$
- Victoria	0.0	$Q_{d,m2} = 445.6$
- Queensland	0.0	$Q_{d,m3} = 294.3$
C. Cheese demand		
- New South Wales	-0.57	$Q_{d,c1} = 30.909 - 0.023 P_{c1}$
- Victoria	-0.49	$Q_{d,c2} = 19.294 - 0.012 P_{c2}$
- Queensland	-0.78	$Q_{d,c3} = 19.302 - 0.017 P_{c3}$
D. Butter demand		
- New South Wales	-0.77	$Q_{d,b1} = 29.518 - 0.032 P_{b1}$
- Victoria	-1.20	$Q_{d,b2} = 35.013 - 0.051 P_{b2}$
- Queensland	-2.38	$Q_{d,b3} = 42.855 - 0.085 P_{b3}$

Source: Davidson, MacAulay and Powell (forthcoming).

Table 2
Results of the Estimation of the Unrestricted Demand Equations for Market Milk, Cheese and Butter in New South Wales, Victoria and Queensland, 1984:3 to 1987:2[a]

Equation	Dependent variable	Constant	$P_{i,r,t}$	$P_{i,r,t}/P_{i,r,t}$	$Y_{r,t}$	$I_{m,t}$	D1	D2	D3	R^2	$\bar{R}^2$	DW
Market milk demand in:												
. NSW	$Q_{m,n,t}$	57252.11	710.026		74.322	0.244	-2458.546	-479.938	2431.798	0.97	0.93	2.13
		(5.13)	(1.59)		(1.14)	(0.88)	(-1.48)	(-0.62)	(3.11)			
. Vic	$Q_{m,u,t}$	125436.6	-426.787		-20.056	1.415	-2136.778	1648.059	-274.122	0.91	0.80	2.51
		(14.48)	(-1.11)		(-0.42)	(5.63)	(-1.42)	(2.75)	(-0.41)			
. Qld	$Q_{m,q,t}$	50854.69	191.1538		2.426	0.215	1551.749	-567.595	266.751	0.92	0.82	1.88
		(10.35)	(0.98)		(0.08)	(1.57)	(2.09)	(-1.46)	(0.65)			
Butter demand in:												
. NSW	$Q_{b,n,t}$	0.738	-0.470	-0.000	-0.001		-0.026	0.044	-0.003	0.47	-0.17	1.93
		(1.35)	(-0.01)	(-0.04)	(-0.25)		(-0.43)	(1.64)	(-0.13)			
. Vic	$Q_{b,v,t}$	1.602	-18.561		-0.001		0.043	0.040	-0.011	0.62	0.30	1.70
		(4.61)	(-0.42)		(-0.20)		(0.64)	(1.15)	(-0.34)			
. Qld	$Q_{b,q,t}$	1.641	53.781	-0.001	-0.005		-0.124	0.037	0.032	0.61	0.15	1.90
		(0.75)	(0.36)	(-0.53)	(-0.76)		(-0.99)	(0.57)	(0.51)			
Cheese demand in:												
. NSW	$Q_{c,n,t}$	0.711	-0.128		0.002		-0.023	0.044	0.022	0.42	-0.07	2.17
		(2.6)	(-0.9)		(1.0)		(-0.4)	(1.7)	(0.8)			
. Vic	$Q_{c,u,t}$	1.550	0.033		-0.002		0.028	0.034	-0.017	0.61	0.28	1.91
		(6.62)	(0.18)		(-0.78)		(0.58)	(1.31)	(-0.68)			
. Qld	$Q_{c,q,t}$	1.591	-0.177		0.001		-0.003	0.015	-0.019	0.51	0.11	1.76
		(6.04)	(-0.98)		(0.46)		(-0.08)	(0.72)	(-0.87)			

a A total of 13 observations were used with an ordinary least squares estimator.
Source: Davidson, MacAulay and Powell (forthcoming).

consistent with the fact that the product type (cheddar) is perceived to be a staple food. Finally, the relatively more elastic response for butter is possibly due to the fact that consumers have a substitute for the product in margarine, (yet in estimating the demand for butter, margarine prices were found to be insignificant).

Data on freight rates between regions were obtained from Henderson Consultants (personal communication, 8/11/89) who undertook a study on transporting dairy products. These rates are presented in Table 3. They apply to bulk packaged butter and cheese and prepackaged milk. They were calculated on a subcontractor cost structure, which tends to be lower than a company fleet structure. The rates for prepackaged milk are 1.35 times greater than the rates for butter and cheese. An interesting fact revealed by these rates is that any route to Melbourne is cheaper than any route from Melbourne. In other words, back-loading rates are a feature of refrigerated transport between the regions. There are a number of problems associated with using these data. First, it is time specific. In other words, it does not account for changes that may occur throughout the year due to changes in the demand for transport services. Second, the method is location specific, as the assumption was given that production and consumption all occur at a single point in each region. Consequently, the freight rates may not adequately reflect the true costs of transporting dairy products from all producers to all consumers within each region. Finally, the freight rates may not fully account for all the costs of trading goods between regions such as packaging, insurance and loading. A resolution of these problems lies in a detailed study of the dairy transport sector.

The marketing margin associated with retailing one litre of milk and one kilogram of butter and cheese in New South Wales, Queensland and Victoria are detailed in Table 4. Initially, margins were derived by subtracting the farm gate price of the milk content in each product and the returns from producing by products, from the retail price of each commodity in question. In the case of the residual products (other) it was assumed that processors received purely the milk content price for the commodity. This simple method tends to be inadequate, as the price margins for Victoria are considerably higher than that in the other states, yet they reputably have the most efficient processing sector. The reason for this discrepancy is that the average farm gate price for milk in Victoria is much lower than in the other states, while the retail price for butter and cheese tend to be higher. In order to correct for this apparent deficiency, the margins in Victoria will be reduced to their New South Wales counterparts. In ensuing sections it will be assumed that these margins remain constant, regardless of the volume of milk sold and any change in prices. While these

Table 3
Freight Rates for Dairy Products

Item	Destination NSW	Vic	Qld	ROA
Source				
Market milk from			(c/l)	
. NSW	0.0	7.4	11.2	11.2
. Vic	8.0	0.0	16.3	8.2
. Qld	8.0	10.9	0.0	14.2
Cheese and butter from			(c/kg)	
. NSW	0.0	5.5	8.3	8.3
. Vic	5.9	0.0	12.1	6.1
. Qld	5.9	8.1	0.0	10.5

Source: Stephen Manders, Henderson Consultants.

Table 4
Marketing Margins for Dairy Products
(c/l)

Item	Units	N.S.W.	Vic	Qld
Market milk	c/l	50.49	56.87	58.21
Cheese	c/kg	225.12	346.23	236.27
Butter	c/kg	15.49	210.39	48.05

Source: NSWDC (1987), *Price Structures.*

assumptions are limiting, they are a necessity, as information on the likely impact such changes may have appear to be non-existent. The processing cost data could be significantly improved upon if a detailed specification of the various components which make up the margins was undertaken, then individual costs could be ascribed to each region. However, in order to undertake this task it is necessary to have a more complete picture of the processing and dairy transport sectors.

In order to link the two levels of the model together, it is necessary to specify the conversion factors between liquid milk and its resultant processed products. The ways of processing whole milk into dairy products are numerous. However, they are constrained by a number of limitations, of which economic factors are perhaps the most important. Processors need to choose a production mix which maximises returns while minimising costs, in order to maximise profits. Furthermore, in the short-term, processors are constrained by the type and capacities of the plant they possess. As milk processing is a highly complex task, processing plants are expensive and tend to be highly specialised. However, this is not to say that some complementary and marginal adjustment does not occur in the production of dairy products. Finally, the output of dairy products is constrained by the physical complexities of converting the raw product. For instance, depending on the milk's quality it takes approximately 9.518 litres of milk to produce 1 kg of cheese, or 18.318 litres to produce 1kg of butter, or 11.7 litres to produce 1 kg of skim milk powder. In Table 5 the milk equivalent conversion factors for converting whole milk into processed products are detailed. It must be noted that producing any product, by-products may result. For example, the production of 1 kg of cheese results in the production of 0.093 kg of butter, while the production of 1 kg of butter will result in either 1.613 kg of skim milk powder or 0.526 kg of casein.

In summary, the intercepts and slopes of the supply of whole milk and demand for market milk, butter and cheese in New South Wales, Queensland and Victoria were specified. In addition, the costs of processing and transporting these products within and between the regions specified above, to the export market and rest of Australia market were detailed, along with the conversion factors used in the processing system. The data used in this study is fraught with problems. The results of the estimation of demand were not impressive. Furthermore, the only processing cost data that could be obtained were marketing margins.

Table 5

Milk Equivalent Conversion Factors
(l/kg)

Product	Conversion factor
Cheese	9.518
Butter	18.318
Powdered milk	
full cream	8.510
skim	11.695
Condensed, concentrated and evaporated milks	
full cream sweetened	2.620
full cream unsweetened	2.810
skim	11.695

Notes: A assumes a fat level of per cent and A solids to fat ratio of percent.
Source: Blyth (1984).

5. Results

The purpose in this section is to bring the various components discussed earlier in this report together, into the spatial equilibrium model and to present the results, which is an attempt to replicate reality. The model was solved using the Rand QP algorithm. The model was run in its constrained form, with restrictions on interstate trade in market milk. The model will be judged to be an adequate representation of the market if it replicates the prices and quantities which existed in the industry in the base year (1986-87). In addition, the sensitivity of the model to changes in elasticities, freight rates and processing costs, will be assessed.

The results from the simulation runs are compared with actual data and are presented in Table 6. In undertaking this task it was assumed that seasonality was not an important factor, that differences in the manufacturing and transport sectors could be fully accounted for by utilising existing marketing margins prevailing in the market and that the dairy industry had a perfectly competitive structure. An attempt was made to replicate the real world and so the transport costs for market milk were set artificially high to account for government policy which tends to restrict this trade between states.

In order to verify the model it is necessary initially to achieve an objective function equal to zero. No published information is available on interstate trade in dairy products. Consequently, it is necessary to rely on the data on quantities produced and consumed in each region in order to come to terms with this trade, backed up by some anecdotal evidence. Clearly, Victoria is the largest cheese and butter producer in Australia. Consequently, it can be asserted that Victoria exports butter and cheese to all other markets. Further, as New South Wales produces such small quantities of these two products, it can be asserted that it is a net importer from Victoria. Finally, from the details specified in Appendix A, it could be the case that Queensland is an isolated market, importing and exporting very little cheese and butter from and to the rest of Australia.

The results of the simulation of the model proved adequate in describing the quantities produced, consumed and traded, but the prices in each market for cheese were 'off the mark'. However, the results for the prices for butter sold in each market were reasonable The clear implication of this result is that more analysis needs to be undertaken on the dairy processing sector.

The results from the sensitivity analysis are presented in Table 7. In undertaking this analysis, processing and transport costs and all elasticities were increased by 50 per cent. The resulting changes are compared with the results obtained from the simulation run which utilised actual transport costs and adjusted processing margins. The results of this analysis suggest that overall, the model is most sensitive to changes in elasticities. However, changes in elasticities will cause large changes in the prices in the model. In addition, changes in freight rates will alter the pattern of trade, while changes in processing margins has most effect on the production of products.

In this section the results of the modelling effort were presented. The model was found to be an adequate, yet not totally compelling, representation of the eastern Australian dairy market. In addition, a sensitivity analysis was undertaken, and it was found that the model is not very robust. Improvements that could be made to this model are the subject of the ultimate section of this paper.

6. Conclusions and Future Directions

The purpose in this paper is to present some of the technical documentation of a spatial equilibrium model of the dairy industry of the eastern Australian mainland states. In undertaking this task, the supply and demand schedules and the processing sector which separates them have been detailed. The model is characterised by three whole milk production regions (New South Wales, Victoria and Queensland) and five retail

Table 6
Results of a Simulation Run of a Preliminary Spatial Equilibrium Model of the Australian Dairy Industry

Item	Units	Actual	Model results
Prices			
Market milk in N.S.W.	c/l.	79.0	79.6
Market milk in Vic.	c/l.	76.0	71.3
Market milk in Qld.	c/l.	85.0	85.6
Cheese in N.S.W.	c/kg.	496.5	457.9
Cheese in Vic.	c/kg.	528.3	441.5
Cheese in Qld.	c/kg.	491.3	452.7
Butter in N.S.W.	c/kg.	355.0	474.2
Butter in Vic.	c/kg.	378.0	451.2
Butter in Qld.	c/kg.	356.0	473.2
Wholemilk in N.S.W.	c/l.	28.5	29.1
Wholemilk in Vic.	c/l.	19.1	14.4
Wholemilk in Qld	c/l.	26.8	27.4
Quantities consumed			
Market milk in N.S.W.	ml.	593.7	593.7
Market milk in Vic.	ml.	445.2	445.2
Market milk in Qld.	ml.	294.3	294.3
Cheese in N.S.W.	kt.	19.7	20.5
Cheese in Vic.	kt.	13.7	14.0
Cheese in Qld.	kt.	9.0	11.5
Cheese in rest of Australia	kt.	3.8	3.8
Cheese in the export market	kt.	38.9	39.4
Butter in N.S.W.	kt.	14.1	11.2
Butter in Vic.	kt.	15.9	12.2
Butter in Qld.	kt.	9.2	2.7
Butter in rest of Australia	kt.	9.0	9.0
Butter in the export market	kt.	31.4	33.7
Quantities produced			
Cheese in N.S.W.	kt.	7.1	12.9
Cheese in Vic.	kt.	72.7	57.2
Cheese in Qld.	kt.	9.0	19.2
Butter in N.S.W.	kt.	0.8	1.2
Butter in Vic.	kt.	90.2	65.7
Butter in .	kt.	9.0	1.8

Table 7
Results of Sensitivity Analysis

Item	Units	Simulation run	Freight rates	Processing costs	Elasticities
Prices					
Pm1	c/l.	79.6	79.2	52.6	105.2
Pm2	c/l	71.3	71.1	45.3	91.3
Pm3	c/l.	85.6	85.5	55.4	108.4
Pc1	c/kg	457.9	456.3	329.4	633.3
Pc2	c/kg.	441.5	440.4	297.6	601.6
Pc3	c/kg.	452.7	453.6	330.5	638.6
Pb1	c/kg.	474.2	460.4	409.8	810.0
Pb2	c/kg.	451.2	448.9	386.8	787.0
Pb3	c/kg.	473.2	459.9	408.8	808.9
Pw1	c/l.	29.1	28.78	27.4	54.7
Pw2	c/l.	14.4	14.3	16.9	34.5
Pw3	c/l.	27.4	27.3	26.3	50.1
Quantities consumed					
Qm1	ml.	593.7	593.7	593.7	593.7
Qm2	ml.	445.2	445.2	445.2	445.2
Qm3	ml.	294.3	294.3	294.3	294.3
Qc1	kt.	20.5	20.6	23.5	23.8
Qc2	kt.	14.0	14.0	15.7	15.7
Qc3	kt.	11.5	11.5	13.6	7.3
Qc4	kt.	3.8	3.8	3.8	3.8
Qc5	kt.	39.4	39.4	39.4	39.4
Qb1	kt.	11.2	11.5	13.2	13.4
Qb2	kt.	12.2	12.3	15.5	15.1
Qb3	kt.	2.7	3.9	9.5	8.5
Qb4	kt.	9.0	9.0	9.0	9.0
Qb5	kt.	33.7	33.7	33.7	33.7
Quantities produced					
Qc1	kt.	12.9	3.3	0.0	0.0
Qc2	kt.	57.2	67.0	82.3	89.2
Qc3	kt.	19.2	19.0	13.6	7.3
Qb1	kt.	1.2	4.2	0.0	0.0
Qb2	kt.	65.7	53.3	70.5	70.7
Qb3	kt.	1.8	0.0	0.0	0.6

[a] All freight rates, processing costs or elasticities increased by 50 percent.

demand regions (the three supplying regions and the rest of Australia and export markets) consuming four products (market milk, butter, cheese and other). These regions are segregated by the costs of transporting the various dairy products between them, while the two market levels in the model are linked by the costs of processing whole milk into its various end uses. In the model all products are specified in units normally associated with the particular product, and are linked by the conversion factors which relate the quantities of whole milk needed in each product. Government regulation of the industry has been incorporated in the model and policy simulations will be carried out on this component. In this section, each part of the model will be reviewed and discussed in terms of its implications for the results.

There are advantages to disaggregating and modelling the Australian Dairy Industry on a state-by-state basis. The industry is regionally based and largely state controlled. So much so, that the industries in each state are significantly different. There are possible payoffs to disaggregating the supply side into intrastate regions given the diverse nature of the dairy industry. In a similar vain, in order to adequately address the problems faced by the dairy industry, it is necessary to account for seasonality. However, further disaggregation of the demand side would not seem to be possible, due to a lack of suitable data. The clear implications for the modelling effort arising from disaggregating the dairy industry into its regional components is that greater explanatory power can be gained. Yet there is a minimum level of disaggregation which can occur, and it is governed by the availability of data.

The ability of any model to explain behaviour in an industry is partly dependent on the quality of the data used. In the dairy industry, data quality and availability is a problem. Consistent and lengthy time-series data are generally not available, and those which are, are not readily verifiable. Trade balance sheets, relating closing stocks, production and imports to opening stocks, consumption and exports on a state basis are not easily derived. In order to balance these items a number of assumptions have to be made in relation to the non-retail sales of various dairy products and trade flows. While many of the data related problems can be resolved, it is not possible to ascertain the extent to which the solutions are affected by such problems. An implication for the modelling effort, is that any future endeavours in this area could be limited and may leave results open to a certain amount of dispute. Yet, it also highlights where attention might be focused to provide data to assist more meaningful analysis of policy options.

The linkages between regions and market levels are one of the most important components of the model. If these links are not specified correctly, the model will not solve in a meaningful manner. In the model, detailed in this paper, it is recognised that the specification of these links could be significantly improved. A further restriction of the current specification of the model is that these links are fixed and independent of the quantities processed and traded. If a greater understanding of these links could be gained, a more flexible specification could be utilised.

Work has commenced on estimating the individual dairy product processing cost functions. The processing sector consists of a wide variety of processes, different processing technology and widely varying costs. Thus it is likely to be difficult to model even if suitable data could be obtained. As a consequence, progress in this area has been slow. Given this problem, a case study approach is currently being considered. The processing sector of the dairy industry is potentially the most important link in the dairy marketing chain. It is this sector which has undergone rapid change in recent years. The sector is a large employer in regional areas and has significant multiplier effects on local economies. Furthermore, processors do have the potential to influence policy in the industry; they are powerful players in the dairy marketing chain due to their relatively small number and strategic positions between numerous producers and numerous retail outlets. There is also the potential for increased vertical integration by this section of the industry. Small (1987) estimated short-run cost functions for the sector. However, her analysis was plagued by data inconsistencies and methodological problems. Furthermore, her study was not incorporated into a general model of the industry, thus limiting the applicability of the results. The problems faced by Small are the same problems that have to be overcome in this study.

In addition to the modifications specified above, it is proposed to extend and disaggregate the spatial equilibrium model of the Eastern Australian dairy industry to account for the processing sector, seasonality and the decentralisation of liquid milk supply. In undertaking these tasks, cost functions of the processing sector by product need to be estimated. Further, quantities of milk supply and supply elasticities need to be obtained from ABARE supply models disaggregated on an intrastate basis. Finally, these factors need to be incorporated into the model. It is expected that these tasks will be complete[illegible] [illegible]e immediate future.

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APPENDIX A

Table A.1

Consumption of Dairy Products in Australia: 1986-87.

Item	Units m.l.	NSW	VIC	QLD	AUST
Whole milk intake	(ml)	906.0	3692.0	604.0	6176.0
Market milk sales	(ml)	593.7	445.2	294.3	1655.7
Available for processing	(ml)	312.3	3246.8	309.7	4520.3
Butter					
opening stock	(kt)	0.065	17.130	0.910	19.760
production	(kt)	0.829	90.214	3.703	103.929
domestic conspt.	(kt)	14.982	15.915	12.679	57.985
interstate exports (imports)	(kt)	(14.119)	32.273	(11.233)	0
international exports	(kt)	0.025	31.431	2.490	35.037
closing stocks	(kt)	0.007	27.725	0.677	30.667
Cheddar cheese					
opening stocks	(kt)	1.719	47.015	4.252	70.410
production	(kt)	7.058	72.689	9.039	123.321
domestic conspt.	(kt)	19.687	12.949	10.844	59.355
interstate exports (Imports)	(kt)	(15.605)	13.730	(1.816)	0
international exports	(kt)	2.902	41.415	0.083	59.985
closing stocks	(kt)	1.793	51.610	4.180	74.391

Source: Bruce Dare (Australian Dairy Corporation Personal Communication).