Articles and Notes

Efficiency Aspects of Transferable Dairy Quotas in New South Wales: A Linear Programming Approach

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In July 1990 the New South Wales Dairy Corporation altered the regulations governing the transferability of market milk supply quotas. These changes allow producers to trade in milk quotas to suit their individual production patterns. In this study, a farm-level analysis of the effects of changes in dairy quota policy in New South Wales was undertaken. In addition, an indication of the effectiveness of these changes, with respect to the original objectives of the policy makers, is provided. This research was based on a linear programming model designed to select the optimal farm plan, including quota transactions and milk production patterns. It was found that a farm could produce more milk for less cost, under a transferable quota scheme, than under the previous fixed quota scheme. This would indicate that transferable quotas can increase the efficiency of dairy production in New South Wales.

1. Introduction

The New South Wales Dairy Corporation's (NSWDC) aim in introducing transferable, or negotiable, quota schemes in July 1990 was to increase the overall efficiency of the New South Wales dairy industry by allowing low-cost producers to purchase quota from higher cost producers. In this way, milk could be produced at an overall lower cost, reducing the pressure on processors to increase the retail price of milk. This, in turn, would increase the price competitiveness of New South Wales milk compared to Victorian milk (Lembit, Topp, Williamson and Beare 1988; Small 1988). The market milk price in New South Wales of 43.18 cents per litre (November 1992) is substantially higher than those in other states (for example, Victorian producers receive 38.31 cents per litre), creating an incentive for suppliers, particularly those from Victoria, to sell market milk in New South Wales in competition with local producers (Small 1988; Industry Commission 1991).

Previous researchers have focussed on likely intrastate structural changes in various regions of New South Wales due to the transferability of quota. The results from that research indicated that quota transferability could increase state-wide efficiency but with negative effects in some milk producing regions. However, previous studies have not looked at the effects on or benefits to individual producers, nor how producers could use transferable quotas to maintain, or increase, farm income (for example Lembit, Topp, Williamson and Beare 1988; Williamson, Topp, Lembit and Beare 1988). This study is a farm-level analysis of the effects of changes in dairy quota policy in New South Wales. It is intended to provide an indication as to the effectiveness of these changes with respect to the original objectives of the policy makers, that is, to increase farmers' incomes.

A fixed quota scheme imposes on a producer the necessity to produce output no matter the cost. In the case of fixed quotas, if a shortfall in the supply of quota milk in any one week of a four week period is not compensated for with extra production in another week of that four week period, the farmer's market milk quota allocation is reduced (NSWDC 1990).

With fixed quotas some producers will produce market milk at a marginal cost greater than the marginal revenue from manufacturing milk. Also, some producers will be able to supply market milk at a marginal cost lower than the marginal revenue that can be generated from manufacturing milk production. The marginal revenue of producers is specified in terms of manufacturing milk prices and quantities as there is no restriction on the production of this type of milk. Therefore, farm profits can

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be maximised at the point where the marginal cost of production is equated with the revenue generated by the extra litre of manufacturing milk supplied. Hence, overall efficiency and profits in the dairy industry could be increased if producers could trade their quotas until the marginal costs of producing an extra litre of milk are equal. Equating the marginal costs of all producers in an industry where output is restricted ensures that the fixed output is produced at least cost (Lembit *et al* 1988).

Another problem in the production of milk is the seasonality of pasture growth, feed prices and individual cow milk production patterns. Therefore, if producers are required to supply the same amount of milk every week, the marginal costs of production will fluctuate with seasonal or climatic factors. To maximise industry profits the individual farmers would need to be able to match fluctuations in milk supply with seasonal changes in inputs used for the production of market milk. A trade in quotas would enable the coordination of these requirements (Neutze 1963; Parish 1963).

Two models were developed to test if the introduction of transferable quotas would increase the efficiency of New South Wales milk production. The first was for a representative farm under the fixed quota scheme, the second for the same farm after the introduction of transferable dairy quotas. The resulting Total Gross Margins (TGMs) from each model were compared to show if, and how, transferable quotas can affect the management and profitability of the representative farm. TGMs were chosen as an indication of efficiency as it is extremely difficult to determine the farm level cost function, and efficiency can be calculated as an increase in the TGM with the same level of fixed resources. This was the case in this study, where the farmer had the same fixed resources available to produce output, milk, but these resources could be combined more efficiently by trading in milk quota, and therefore increase the output of the farm (Tisdell 1982).

The hypothesis tested in this study was that the use of transferable dairy quotas, in place of fixed quotas, would not increase the TGM of the farm. The TGM under the fixed milk quota scheme and the TGM under transferable dairy quotas were compared to test this hypothesis.

2. Method of Analysis

Linear programming was selected as the analytical method for this research. It is a common method for examining questions which relate limited resources to the goals of the decision maker. Profit maximisation was the objective specified in this analysis, and the linear programming model was used to allocate resources, up to their respective limits, to the activities of the farm, to achieve this goal.

A linear programming model was developed to determine the optimal production pattern and quota transactions that should be undertaken in each quota period. Each period is four weeks in duration; hence, there are thirteen periods per year, with period one beginning in July of each year. The model is based on information supplied by a case-study farmer. Additional data were obtained from NSW Agriculture and the quota exchange prices from the NSWDC. These data were then adapted to develop a representative farm located in the upper Hunter Valley of New South Wales.

The farm was assumed to be representative of dairy farms in the Upper Hunter Valley as most dairy farms in this region are managed in a similar manner. That is, they have an irrigated lucerne-based pasture rotation and are usually owner-operated, with casual labour used at peak times such as milking (Hunter Dairy Development Group 1990).

The underlying assumptions of the model were that: the farmer is a profit maximiser ; the output from the farm follows a seasonal pattern represented by average milk output data supplied by the farmer ; and the farmer can instantaneously adjust his or her production pattern to the proposed optimal plan.

The results obtained from the model were a steady state representation of the optimal farm plan. No information was provided on how the farmer could change the production pattern to conform to the solution nor the financial implications of such a change-over period.

Sensitivity analysis was used to determine the stability of the optimal solution. The effects of changes in prices of market and manufacturing milk and variations in the exchange prices for milk quota were considered in the model. The effects of changes in interest rates were also considered as they are the major opportunity cost of purchasing quota on the exchange. Different pasture rotations were then analysed to determine which was the most efficient rotation in achieving the farmer's goals.

3. Model Description

The model was designed to select the calving pattern and quota allocation that maximises the TGM of the farm. Included in the objective function was the income generated from market and manufacturing milk sales in each of the 13 quota periods and the opportunity costs or benefits of quota transactions. Herd and shed variable costs were also included. These costs are those necessary to maintain the productivity of the cows. Other costs in the objective function were those associated with feed production and/or purchases and labour. The only other income-producing activity on the farm was a lucerne hay enterprise, and this was included in the analysis.

The simplex tableau of the transferable-quota model is presented in Figure 1. The model has 227 columns and 176 rows. The fixed quota model differs slightly to the transferable quota model, as it does not include any quota transaction activities and the maximum purchase and expenditure constraints are not included. The maximum purchase constraint was included as the original quota rules limited the total amount of quota that could be purchased in any twelve month period. The expenditure constraint was the net maximum amount of capital the farmer was prepared to allocate towards the purchase of quota, after allowing for quota sales income to be included. Also, the maximum quota sales constraints which are set to be less than or equal to the initial quota allocation in the transferable quota model, are equalities in the fixed quota model. Another constraint built into the model is a safety margin. This safety margin is the minimum amount of market milk the farmer should ideally produce to ensure that, in the event of a problem such as low production due to heat stress in the cows, the allocated quota is still supplied to the NSWDC. A complete specification of these models and the data used to construct them are presented in Tozer (1991). Appendices 1 and 2 describe variables and constraints incorporated in the models.

The initial quota allocation of the farm is the weekly allocation prior to the introduction of transferable quotas. In the transferable quota scheme all the quota a producer has on hand is eligible for sale. Under the rules of the negotiable scheme, producers who are entitled to purchase quota, can acquire a maximum of 104 000 litres in any one calendar year (NSWDC 1990).

In order to purchase additional quota for a particular period, a farmer must have produced at least 125 per cent of the current quota allocation in any one of the last three years. Hence, if producers buy extra quota, they must qualify under this new quota level if they wish to purchase more quota in subsequent years (NSWDC 1990). Prices for quota transactions were based on an average of the price paid for quota, in each period, in the first year of quota exchanges. The opportunity cost of quota was the average price of quota for the specified period multiplied by the current real interest rate.

The feed production activities in the model include annual and perennial pastures, fodder cropping and grain and hay purchases. Feed value was calculated on a per period basis. Inter-seasonal feed transfers were incorporated into the model, along with a decision between making hay or grazing some of the lucerne paddocks.

Nutritional requirements of the livestock were specified on the basis of rations per period, but were calculated on a daily basis. Both maximum dry matter intake and minimum metabolizable energy requirements were calculated. Allowance was made in these calculations for variations in milk yield and calving influences on feed intake.

Several methods were used to verify the model and the data included in it. An initial model was constructed and the farmer was consulted. The farmer suggested several modifications to make the model

Figure 1: Diagrammatic Representation of the Transferable Quota Matrix

Objective Function	MIP1 M13P13 -288	SP 1-13 *	SMA 1-13 *	SQ 1-13 *	BQ 1-13 *	Lucerne Pastures GM/ha	Pastures GM/ha	BB 1-13 *	BM 1-13 *	BS 1-13 *	TR12 TR131 *	TRB1 TRB13 *	TRM1 TRM13 *	Buyhay 1-13 -140	FB 1-13 0	FM 1-13 0	FS 1-13 0	CASLAB 1-13 -9	FTR 1-13 0	RHS MAX
MMPS 1-13	-a	1	1	-1	1															=0
LABP 1-13	1.4					b	c											-1		≤312
MEP 1-13	d					-e	-f							-5236	-11782	-11524	-12212		-i, j	≤0
QTP 1-13		1		1	-1															≤21600
MAXEXP					g															≤5000
MAXPUR				-h	g															≤102000
MAXS 1-13				1							-1,1									≤21600
BAR 1-13								1				-1,1			-1					=0
MAZ 1-13									1				-1,1			-1				=0
SOR 1-13										1							-1			=0
SILP 1-13								1	1	1	-1,1	-1,1	-1,1		-1	-1	-1			≤70
MAXLAB 1-13																		1		≤128
MAXFTR 1-13																			1	≤0
MAXG 1-13	k														860	860	860			≤0
MAXM 1-13	1																			≤120
LAND						1	1													≤35
NIGHT							1													=4.9
ROTAT						1	-4													≤0
LUCERNE						1														≥24.88
HAY														1						≤250

a = milk production per cow in each period.
b, c = labour requirements per period for each pasture.
d = ME requirements per cow per period.
e,f = ME/kg DM/period.
g = average purchase price of quota per period (NSWDC 1991).
-h = average sales price of quota per period (NSWDC 1991).
-i,j = DM of feed transferred between each period.
k = maximum grain intake per cow per period.
* = objective function values described in Appendix 2.
-1,1 = indicates transfers between periods within activities

Variable and Constraint Names are listed in Appendix 1 more applicable to the representative farm. Officers of NSW Agriculture ensured that there were no deficiencies or errors in the feed supply and milk production data.

The stability of the model and the sensitivity of variables included in the model were extensively tested. This testing was carried out on the overall variable costs of milk production which were increased by 10-50 per cent. A comparison of milk production, both market and manufacturing, was made between the fixed and transferable quota models as costs were increased to analyse the changes in management that would occur. Other sensitivity tests were conducted on the price of market and manufacturing milk. The effect of increases in the price of market milk, and of rises and falls in the price of manufacturing milk, were tested.

Alterations in interest rates and maximum expenditure were also tested. The sensitivity of the objective function to increases in all quota prices was checked, along with a test on the effects of changes in winter period quota prices. This test was justified on the basis of the current low cost of these quotas because if demand for quota in these periods increases, the market clearing price would be expected to also rise.

The results of this testing showed that increases in the variable costs of production eventually lead to a reduction in the amount of milk produced (Table 1). This occurs because the marginal costs of increased production exceed the marginal returns from this production (Tozer 1991).

4. Results

The analysis of the results of the two models showed that the transferable scheme provided a higher TGM than did the fixed-quota scheme. Sensitivity analysis indicated that the optimal solution is relatively insensitive to changes in the value of most variables included in the models. The most significant effects occurred when the maximum purchase and expenditure constraints were relaxed.

4.1 Fixed Quota Model

To maximise TGM in the fixed quota model, cows should calve in periods four and nine. By doing this the farmer would achieve a TGM of $110 455, or $3100/ha (Tables 1 and 2). This optimal calving pattern is very different to the accepted norm of calving a constant number of cows in each period. The traditional pattern maintains an even herd size throughout the year, a regular flow of "fresh" cows into the herd and a constant flow of milk. If this constant number of lactating cows was forced into the farm plan, the objective function value could be reduced by up to $67 per cow per period.

There was a very small band of allowable changes in the price of manufacturing milk before changes occurred in the optimal solution. The range of this band was -0.002 c/L to + 0.01 c/L, indicating that the optimal solution would vary with small fluctuations in the manufacturing milk price. However, any realistic changes in prices would not have a large impact on the objective function value. The stability of this model was tested to ensure that changes in these parameters did not markedly affect the optimal solution.

4.2 Transferable Quota Model

To maximise TGM under the transferable quota scheme, cows should calve in periods six and nine. This would result in a TGM of $120 466, or $3385/ha (Tables 1 and 2). Also, the model solution indicated that it was most profitable to purchase quota in periods two, eleven, twelve and thirteen, and sell quota in periods four and five.

The optimal plan contained several differences to that of the fixed-quota model. There were periods in which one of the two types of milk were not supplied. No market milk was delivered in period five, and no manufacturing milk, other than that required for the safety margin, was supplied in periods two, eight, eleven and thirteen. These results indicated that in periods in which only one type of milk was sold, the marginal revenue from the sale of that milk exceeded the marginal revenue from the other type of milk and, assuming the same marginal cost for both types of milk, a higher gross margin is achieved.

Table 1: Sensitivity of Solution to Variable Cost Increases

OPERATION	TGM ($)	QUOTA (L)	BOUGHT QUOTA (L)	PERIODS QUOTA PURCHASED	SOLD QUOTA (L)	PERIODS QUOTA SOLD	COWS CALVE IN PERIOD	MARKET MILK & SAFETY MARGIN (L/YEAR)	MANUF. MILK (L/YEAR)	TOTAL MILK (L/YEAR)	PERIODS NO MKT MILK SUPPLIED	PERIODS NO MANUF MILK SUPPLIED
BASE												
TRANSFERABLE	120466	345331	104000	2, 11-13	37465	4,5	6,9	431664	308879	740543	5	2,8,11,13
FIXED	110455	280800					4,9	351000	394345	745345		
COST CHANGES												
TRANSFERABLE QUOTA MODEL												
COSTS + 10%	110312	345331	104000	2, 11-13	37465	4,5	6,9	431664	308879	740543	5	2,8,11,13
COSTS + 20%	100517	345331	104000	2, 11,13	37465	4,5	6,9	431664	308879	740543	5	2,8,11,13
COSTS + 30%	93068	345214	104000	2, 11,13	37582	4,5	6,9	431518	308690	740208	5	2,8,11,13
COSTS + 40%	83986	345270	104000	2, 11,13	37527	4,5,8	6,9	431587	308778	740365	5	2,8,11,13
COSTS + 50%	77371	342515	98006	1,2,10-13	40280	3-5,7,8	6,7,9	428144	62487	490631	5	1-3,6-8,10-13
FIXED QUOTA MODEL												
COSTS + 10%	99962	280800					5,6,9	351000	389802	740802		5,8
COSTS + 20%	90148	280800					5,6,9	351000	389812	740812		5,8
COSTS + 30%	82708	280800					5,6,9	351000	389812	740812		5,8
COSTS + 40%	73982	280800					4,5,6,9	351000	216601	567601		3,4,5,7,8

Table 2: Summary of Results of Fixed Quota and Transferable Quota Models (Level Per Period)

Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Cows Calved TQ						32			88					120
Cows Calved FQ				47					73					120
Mkt. Milk Production TQ	27000	47942	27000	7167		27000	27000	27000	27000	27000	89940	30755	66863	431667
Mkt. Milk Production FQ	27000	27000	27000	27000	27000	27000	27000	27000	27000	27000	27000	27000	27000	351000
Man. Milk Production TQ	29831		13336	20550	23304	21958	2887		76019	73690		47308		308883
Man. Milk Production FQ	22219	5463	356	39945	36815	29277	8146	3253	64438	61241	51388	40836	30975	394352
Sell Quota TQ				15866	21600									37466
Buy Quota TQ		16754									50352	3004	31890	70110
Feed (all in Tonnes)														
Buy TQ	37	64		16	12	31		10	75	85	48		11	389
Buy FQ	37	39		40	37	46		14	115	45	47		8	428
Feed TQ	37	33	32	16	12	29	2	10	45	45	48	42	39	390
Feed FQ	37	20	19	40	37	36	10	14	45	45	47	41	38	429
Store TQ		32				2			30	70	70	28		232
Store FQ		19				10			70	70	70	29		268

LEVELS OF ANNUAL ACTIVITIES (hectares)

	TQ	FQ
Lucerne Hay	13.40	18.34
Lucerne, Ryegrass & Clover	11.47	6.50
Kikuyu, Ryegrass & Clover	4.90	4.90
Sudax and Oats	6.33	6.33

TQ = Transferable Quota Model Results
FQ = Fixed Quota Model Results

Most quota purchases occurred in the low-cost quota periods of winter. Quota purchases were constrained by the expenditure and purchase maximums set by the NSWDC. Thus quota was purchased only in periods with the highest returns. Quota was sold in periods with the highest selling price, or where the marginal costs of production exceed the marginal revenue of the output.

An outcome of the optimal plan that could cause problems in the manufacturing sector of the industry was the reduction in manufacturing milk, of approximately 86 000 L/year, supplied by the farmer. Another interesting result was that of the total milk produced; under the fixed-quota scheme 745 000L would be produced, whereas with the use of transferable quotas only 740 000L would be produced, even though TGM has increased by approximately $10 000.

4.3 Sensitivity Analysis

The results of the sensitivity analysis are reported in Table 3. These results indicate that the model is reasonably stable, with a range of Total Gross Margins from $111 732 to $135 456. The general range of TGMs in the sensitivity analysis was within ten per cent of the base figure of $120 466. Although this range is relatively broad, the upper limit is probably not achievable as it would require a five cent per litre increase in the farm gate price of market milk which, at present, is highly unlikely. However the lower limit, when the price of manufacturing milk falls by two cents per litre, may be possible given the volatility of the international dairy market.

Changes in interest rates and quota prices seemed to have a negligible effect on both TGM and milk production. Hence, it appears the model is insensitive to either the cost of quotas or the opportunity cost of money. A change in pasture rotations was also tested to determine if a different rotation would affect the cost of producing milk. To some extent it does, as the quantity of milk produced is constant, but the TGM has increased indicating that at times farmers do not optimise the feed costs; that is, the pasture:grain:concentrate feed mix is not optimal. Also, this indicated that it was more profitable for the farmer to grow ryegrass and clover to feed cows for milk production than growing lucerne for hay.

4.4 Further Analysis

In order to determine whether transferable dairy quotas increase efficiency in the industry, the model farmer was allowed to purchase an unlimited amount of quota under either the fixed or transferable quota schemes. That is, there were no purchase or capital limits, and the physical resources of the farm determined the maximum amount of quota purchased, while all other physical constraints of the farm remained constant.

In the fixed-quota model the same quantity of quota was to be purchased and supplied in each period. The results of this analysis suggested that under the fixed quota scheme an extra quota of 26 722 litres per period was purchased, giving a market milk requirement in each period of 60 402 litres, for a total purchase amount for the 13 periods of 347 386 litres (Table 4). The purchase price for quota was assumed to be $15/L, which converts into an annual cost of $1.53 per litre. This price was the amount producers were charged in the last surrender pool allocation operated by the NSWDC. The surrender pool was operated by the NSWDC, and it allowed farmers who wished to leave the dairy industry and who held quota, to "surrender" their quota, at a price determined by the NSWDC, to the NSWDC. This surrendered quota was then sold to farmers wishing to purchase additional quota.

Under the transferable quota scheme, it was optimal for the farmer to purchase an additional 372 197 litres of quota per year. The quota purchases varied in line with changes in production patterns and no constant quota purchase level was apparent. Amounts of quota purchased ranged from 19 155 L to 36 582 L per period.

The TGM for each model also varied markedly. With a fixed-quota requirement and unrestricted purchases, the TGM for the farm was $128 691, whilst under the transferable quota scheme the TGM was approximately $167 496, an increase of $38 805. These results indicate that allowing farmers to match milk supply to suit pasture growth patterns and times of relatively cheap feed supplies could result in increased returns and/or reduced

Table 3: Summary of General Sensitivity Tests

OPERATION	TGM ($)	QUOTA (L)	BOUGHT QUOTA (L)	PERIODS QUOTA PURCHASED	SOLD QUOTA (L)	PERIODS QUOTA SOLD	COWS CALVE IN PERIOD	MARKET MILK & SAFETY MARGIN (L/YEAR)	MANUF. MILK (L/YEAR)	TOTAL MILK (L/YEAR)	PERIODS NO MKT MILK SUPPLIED	PERIODS NO MANUF. MILK SUPPLIED
MARKET MILK PRICE CHANGES (in Cents per Litre)												
Price + 1C	123521	345331	104000	2, 11-13	37465	4,5	6,9	431664	308879	740543	5	2,8,11,13
Price + 3C	129484	345331	104000	2, 11-13	37465	4,5	6,9	431664	308879	740543	5	2,8,11,13
Price + 5C	135456	345748	104000	2, 11-13	37048	5,6	6,9	432185	308358	740543	5	2,8,11,13
MANUFACTURING MILK PRICE CHANGES (in Cents per Litre)												
Price - 2C	111732	345331	104000	2, 11-13	37465	4,5	6,9	431664	308789	740453	5	2,8,11,13
Price - 1C	116116	345331	104000	2, 11-13	37465	4,5	6,9	431664	308789	740453	5	2,8,11,13
Price + 1C	124780	345063	104000	2, 11-13	37732	4,5,6	6,9	431329	309214	740453	4	2,5,8,11,13
CHANGE IN INTEREST RATES												
Interest 13%	120568	345374	104000	2, 11-13	37423	4,5	6,9	431718	311182	742900	5	2,8,11,13
Interest 20%	120382	345374	104000	2, 11-13	37423	4,5	6,9	431718	311182	742900	5	2,8,11,13
CHANGE IN PASTURE (RC = Ryegrass & Clover Requirements, Unrest = No Pasture Constraints)												
RC> 4.9	128124	345331	104000	2, 11-13	37048	5,6	6,9	431664	308879	740543	5	2,8,11,13
Unrest	130503	345166	104000	2, 11-13	37630	4,5,8	6,9	431457	307071	738528	5	2,7,8,11,13
CHANGE IN MAXIMUM EXPENDITURE CONSTRAINT (Maxexp) ($)												
Maxexp 7500	122114	355400	104000	2, 11-13	27397	4,5	6,9	444250	296294	740544	5	2,8,11,13
Maxexp 10000	123757	365330	104000	2, 11-13	17456	5	6,9	456662	283881	740543		2,8,11,13
CHANGE IN QUOTA PRICES (Win = Winter Quota Price)												
+ 10%	120116	343508	104000	2, 11-13	39289	4,5	6,9	429385	311159	740544	5	2,8,11,13
+ 20%	119805	341918	104000	2, 11-13	40872	4,5	5,9	427397	315494	742891	5	2,8,11,13
Win + 10%	119345	339561	104000	2, 11-13	43236	4,5,6	5,9	424451	318449	742900	4,5	2,8,11,13
Win + 20%	118474	335766	104000	2, 10, 11	47032	4,5,6	4,9	419707	324105	743812	4,5	2,8,10,11
CHANGE IN MAXIMUM PURCHASE CONSTRAINT (Maxpur)												
Maxpur>0	125612	390830	239702	1-3,10-13	129600	4-9	6,9	488538	249702	738240	4-9	1,2,10-13
Maxexp 7500	127819	405202	275600	1-3,10-13	151200	4-9	2,4,6,7,9 11,13	506503	242547	749050	4-9	1-3,10-13

Table 4: Summary of Results of Unrestricted Purchase Fixed Quota and Transferable Quota Models (Level Per Period)

Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Cows Calved TQ		20		20	15	5	20		20		20		20	140
Cows Calved FQ	8	12	11	10	11	10	11	19	19	19	3	17	17	151
Mkt. Milk Production TQ	56885	60299	50944	61700	65830	65352	70547	63395	69634	62368	66986	59762	62615	816318
Mkt. Milk Production FQ	60402	60402	60402	60402	60402	60402	60402	60402	60402	60402	60402	60402	60402	785226
Man. Milk Production TQ														
Man. Milk Production FQ					992	2386		1085	8046	3258	6360		2292	24419
Buy Quota TQ	23908	36582	19155	27760	31065	30681	34837	29116	24107	28294	31988	26211	28493	372197
Feed (all in Tonnes)														
Buy TQ	41	78		43	43	83		39	111	45	46		15	544
Buy FQ	41	83		41	41	75		37	109	44	45		12	528
Feed TQ	41	41	37	43	43	43	41	39	41	45	46	42	43	545
Feed FQ	41	40	43	41	41	41	34	37	39	44	45	39	42	527
Store TQ		37				41			70	70	70	28		316
Store FQ		43				34			70	70	70	31		318

LEVELS OF ANNUAL ACTIVITIES (hectares)

	TQ	FQ
Lucerne Hay	24.84	23.22
Lucerne, Ryegrass & Clover	0.00	1.65
Kikuyu, Ryegrass & Clover	4.90	4.90
Sudax and Oats	6.33	6.33

TQ = Transferable Quota Model Results
FQ = Fixed Quota Model Results

costs. Hence, a likely outcome is an increase in efficiency of milk production. If this increase in efficiency was achieved at the farm level, then it would be expected that the state and national industries would also become more efficient.

The proposed number of cows to be milked, and the suggested amount of grain to be purchased under the transferable scheme did not change as would have been expected. With a higher number of cows it would be expected that more grain would be consumed. However, under the transferable scheme the model solution suggested that 140 cows would be milked, compared to 151 in the fixed quota proposal. But, more grain (17 tonnes) would be purchased under the transferable quota scheme than the fixed quota scheme, indicating a higher grain intake per head in this proposal (Table 3). This would imply that the marginal revenue from feeding grain at critical production stages exceeds the marginal costs of this grain.

One result which was similar in both models was the area of lucerne sown for hay production. Both models suggested that all, or most, of the land available for lucerne rotations be used to produce lucerne hay, instead of using some of this area for lucerne-based pastures as in earlier results. This would seem to imply that feeding grain to cows provided higher nutritional value than grazing lucerne-based pastures, and the marginal costs of feeding grain were lower than the marginal costs of producing lucerne pastures. Also, the marginal revenue of lucerne hay production was greater than the marginal revenue of milk sales. That is, the revenue generated from a limiting factor (ie. land or labour) is higher when used for hay production rather than in the dairy.

5. Discussion

Transferable dairy quotas have the potential to increase the efficiency of the dairy industry as producers can trade in quota to match their individual production patterns, the price of quota and the relative prices of manufacturing and market milk. The results of this analysis showed that by trading in quota, the farmer could increase the TGM of the dairy activities by about $10 000 above the fixed quota situation. This increase in TGM was achieved even though less milk was produced in the transferable quota model. Hence, milk can be produced at less cost to producers when they are allowed to trade in quotas so that milk production can be matched to periods of relatively low feed cost.

If producers wish to maximise the returns from their farms they must be prepared to make some significant changes to their normal management practices. The possible changes to the farm plan include calving large numbers of cows once or twice a year, instead of calving small groups at regular intervals. By calving cows in one or two periods, farmers can take advantage of high marginal returns relative to the costs of production, or use some surplus labour in low labour usage times.

Delivery of only one type of milk (ie. market or manufacturing) in a particular period will also increase returns. The decision to deliver one type of milk or another depends on the relative returns of each product, the costs of purchasing additional quota and/or the returns available from selling high-priced quota. If the price of additional quota is too high (ie. the marginal returns from the purchase of this additional quota are less than the marginal price of market milk) the farmer would supply market milk up to the level of their current quota and the rest of the milk will be delivered as manufacturing milk.

When producers are allowed to purchase as much quota as possible, given the physical resources of the farm, the returns under the transferable dairy quota scheme were far greater than the gross margin possible when operating within a fixed quota scheme. This occurred because farmers were able to more closely match nutritional requirements of their cows, the milk yield per cow and seasonal pasture patterns in order to maximise the gross margin of the milking activities. This was in contrast to a farmer operating under a fixed quota scheme who must supply the same quantity of milk to the NSWDC every week.

A major implication of transferable dairy quotas is the reduction in milk supplied to manufacturers, which could cause the structure or location of this sector to alter, potentially affecting many other industries which service the dairy factories. If most producers followed an optimal production pattern as suggested in this model, the quantity of manufacturing milk would decline markedly as producers sought to maximize their profits, by producing higher value market milk through the purchase of dairy quotas that suited their individual production pattern. The production of manufacturing milk would only occur when it was profitable to do so. Also, manufacturers may face a more pronounced seasonal pattern of supply, as producers would try to minimise manufacturing milk production in the high production cost periods (in this case in the hot summer months and the wetter winter months).

In the optimal plan there are three periods in the winter where no manufacturing milk is supplied, even though the local manufacturer offers a winter incentive to producers to maintain their winter manufacturing-milk production. This would imply that the manufacturers may have to increase this incentive to induce producers to supply more milk in winter. In the sensitivity testing undertaken, the price of manufacturing milk was increased by $0.01 per litre, and this increase had a marginal impact (an increase of 425L) on total manufacturing milk supplied.

The major source of inefficiency in quota allocation is the rule concerning the maximum allowable purchases by producers. This rule limits the purchases of quota in any one year to 104 000 litres. Producers who are low-cost producers cannot buy any more than this amount of quota. They must then undergo a new qualification period before they can purchase more quota. The aim of increasing the efficiency of the New South Wales market milk sector is to some extent restricted by this rule. Although milk is being produced at a lower cost than under the fixed quota scheme, the costs of production could be reduced further, and producer incomes increased, if this rule was relaxed. In this study the case-study farmer's TGM increased by approximately $40 000, or 30 per cent, when the policy concerning maximum purchases of quota was relaxed.

6. Conclusion

The results of this research support the view that the economic efficiency of an industry can be increased when transferable quotas rather than fixed quotas are used. This conclusion was reached after the analysis of a case-study dairy farm using a linear programming model depicting the constraints and activities of this farm. A further increase in on-farm income is possible if the controller of the quota scheme, the NSWDC, relaxed the rule governing the maximum amount of quota that can be purchased in a calendar year. However, if this occurred, the supply of milk to manufacturers would fall as producers would seek to supply the market which yielded the highest returns. On the other hand producers seeking to leave the industry could sell their quota to those remaining in the industry, who now produce manufacturing milk, therefore lowering the supply of manufacturing milk. Also, the demand for quota would increase as competition is less restricted, hence the price of quota may rise (as quota supply is fixed) and the marginal returns from producing market milk may have to increase to maintain on-farm income. Therefore, producers who sought to buy new quota would have to be more efficient than previously.

As the model developed in this study was a steady state, one-year representation of the case-study farm, no indication was provided as to the most profitable way to achieve this final steady state. Hence, there are avenues for development of the model into a dynamic or multi-period programming model in order to provide a complete picture of the best method to achieve the optimal solution. The model could also be expanded to include time, as the producer may be able to attain a similar TGM, but only work on the dairy for ten or eleven periods of the year. Therefore the model could be adapted to include some goal programming to provide a "holiday" for the farmer.

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Appendix 1: Model Variables and Constraints

SMA1-13	Manufacturing milk price in period one-thirteen
SP1-13	Equalized market milk price in period one-thirteen
MEP1-13	Metabolizable energy requirement per period
DMI1-13	Dry matter intake in kg per period
M1P1-M13P13	Cow calving in period one-thirteen
SQ1-13	Sell period one-thirteen quota
BQ1-13	Buy period one-thirteen quota
LUCHAY	Lucerne hay making activity
LRC	Lucerne, ryegrass and white clover pasture
RC	Ryegrass and clover pasture
KRC	Kikuyu, ryegrass and clover pasture
SUDOAT	Forage sudax and oats rotation pasture
GRLUC	Grazing lucerne activity
CASLAB1-13	Casual labour available in period one-thirteen
FB1-13	Feed barley in period one-thirteen
FS1-13	Feed sorghum in period one-thirteen
FM1-13	Feed maize in period one-thirteen
FTR1-13	Transfer standing feed from period one-thirteen to period two-one
TRB1-13	Transfer barley in store from period one-thirteen to period two-one
TRM1-13	Transfer maize in store from period one-thirteen to period two-one
TR12-131	Transfer sorghum in store from period one-thirteen to period two-one
MAXPUR	Maximum allowable quota purchase
MAXEXP	Maximum expenditure on quota
BUYHAY1-13	Buy hay in periods one to thirteen
MMPS1-13	Milk production in periods one to thirteen
LAB1-13	Labour available in periods one to thirteen
QTP1-13	Quota transactions in periods one to thirteen
MAXS1-13	Maximum quota sales in periods one to thirteen
BAR1-13	Barley purchased, stored or fed out in periods one to thirteen
MAZ1-13	Maize purchased, stored or fed out in periods one to thirteen
SOR1-13	Sorghum purchased, stored or fed out in periods one to thirteen
SILP1-13	Available silo capacity in each period
MAXLAB1-13	Maximum casual labour available in each period
MAXFTR1-13	Maximum feed transfers in each period
MAXG1-13	Maximum grain content of diet in each period
MAXM1-13	Maximum number of cows to be milked in each period
LAND	Land available for pastures or crops
NIGHT	Amount of land to be set aside for night paddocks
ROTAT	Lucerne rotational constraint
HAY	Maximum capacity of hay shed

Appendix 2: Definition of Terms in Objective Function for Figure 1

M1P1 - M13P13	Variable costs per cow derived from on-farm milk cost data
SP1 - SP13	Weighted market milk price based on manufacturing milk price, percentage of milk acquired by the NSWDC and the market milk levy
SMA1 - SMA13	Manufacturing milk price based on fat and protein content of the milk supplied. The price for manufacturing milk supplied in winter is higher due to winter incentive paid to producers during this seasonal shortfall
SQ1 - SQ13	Average price of quota (in cents/L)
BQ1 - BQ13	Average price of quota (in cents/L)
Pastures GM/ha	Gross margin per hectare for each crop/pasture rotation based on farm level data and information supplied by NSW Agriculture
BB1 - BB13	Long-term average price for barley delivered on-farm (Davies 1987)
BM1 - BM13	Long-term average price for maize delivered on-farm (Davies 1987)
BS1 - BS13	Long-term average price for sorghum delivered on-farm (Davies 1987)
TR12 - TR131	Opportunity cost of transferring sorghum between periods based on an interest rate of 17%
TRB1 - TRB13	Opportunity cost of transferring barley between periods based on an interest rate of 17%
TRM1 - TRM13	Opportunity cost of transferring maize between periods based on an interest rate of 17%
BUYHAY1 - 13	Average purchase price of hay in each of the quota periods
FB1 - FB13	Costs of feeding barley in each period
FM1 - FM13	Costs of feeding maize in each period
FS1 - FS13	Costs of feeding sorghum in each period
CASLAB1 - 13	Cost of hiring casual labour
FTR1 - FTR13	Standing feed transfers between periods