Paper Presented to the 36th Annual Conference
of the
Australian Agricultural Economics Society
Canberra, February 10-12,1992.

EFFICIENCY ASPECTS OF TRANSFERABLE DAIRY QUOTAS IN NSW: A LINEAR PROGRAMMING APPROACH.

Peter R. Tozer*

* Department of Agricultural Economics and Business Management
University of New England.
Armidale. N.S.W.

1. INTRODUCTION

The New South Wales Dairy Corporation's (NSWDC) aim in introducing transferable, or negotiable, quota schemes was to increase the overall efficiency of the New South Wales dairy industry by allowing low cost producers to purchase quota from higher cost milk suppliers. 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). Market milk prices in New South Wales are currently substantially higher than those in other states, creating an incentive for suppliers, particularly those from Victoria, to sell market milk in New South Wales in competition with local producers (Small 1988).

Previous researchers have focused on likely intrastate structural changes in various regions of New South Wales due to the transferability of quota. The results from this research indicated that quota transferability could increase overall state-wide efficiency but with negative effects in some milk producing regions of New South Wales. However, none have looked at the effects or benefits to individual producers, nor have they considered how producers could use transferable quotas to maintain, or increase, farm income (Lembit, Topp, Williamson and Beare 1988, Williamson, Topp, Lembit and Beare 1988).

The research conducted in this study is a farm-level analysis of the effects of changes in dairy quota policy in NSW and will 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 what the cost. In the case of fixed quotas dairy farmers must supply their quota allocation each and every week of the year. If they do not fulfil this requirement they are penalised by having their quota 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. 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

lactation curves of cows. 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 farmers would need to be able to match fluctuations in supply with seasonal changes in demand for 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 the New South Wales dairy industry. The first was for a farm under the fixed quota scheme, the second for the farm after the introduction of transferable dairy quotas. The resulting Total Gross Margins (TGMs) from each model will be 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 profit, or TGM, with the same level of resources. This is the case in this study, the farmer has the same physical resources available to him to produce his output, milk, but he can combine these resources more efficiently by trading in milk quota, and therefore increase the output of his farm, (Tisdell 1982).

The hypothesis to be tested in this study is that the use of transferable dairy quotas, in place of fixed quotas, will not increase the Total Gross Margin (TGM) of the farm. Using the results of the model it will be possible to compare the TGM under the fixed milk quota scheme and the TGM under transferable dairy quotas.

2. METHOD OF ANALYSIS

Linear programming was selected as the analytical method for this research. It is an ideal method for examining questions which relate limited resources to the goals of the decision maker. Profit maximisation is the objective specified in this analysis and the linear programming model will be 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 period. Each period is four weeks in duration, hence there are thirteen periods per year, with period one beginning in July of each year. This model is based on information supplied by a case-study farmer. Additional data was obtained from New South Wales Agriculture and the quota exchange prices from the NSWDC. This data was then adapted to develop a representative farm located in the upper Hunter Valley of New South Wales.

The underlying assumptions of the model are 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 are a steady state representation of the optimal farm plan. No information is provided on how a farmer could change his production pattern to conform to the solution nor the financial implications of such a change-over period.

The farm is 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).

Sensitivity analysis is 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 are considered in the model. The effects of changes in interest rates are also considered as they are the major opportunity cost of purchasing quota on the exchange. Different pasture rotations are then analysed to determine which is the most efficient rotation in achieving the farmer's goals.

3. MODEL DESCRIPTION

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

The simplex tableau of the transferable quota model matrix 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, such as selling or buying quota, and the maximum purchase and expenditure constraints are not included. Also, the maximum quota sales constraints which are set to less than or equal to the initial quota allocation in the transferable quota model, are equalities in the fixed quota model. The two models are different to account for the fixity of quota in the fixed quota scenario. A complete specification of these models and the data used to construct them are presented in Tozer (1991).

FIGURE 1

Diagrammatic Representation of the Transferable Quota matrix

Objective Function	M_1P_1 $M_{13}P_{13}$ -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	l																			≤ 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 = 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 discussed in Chapter Five (Tozer 1991).
-1,1 = indicates transfers between periods within activities

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

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

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 102 000 litres in any one calendar year (NSWDC 1990). The farmer can also set a maximum amount of capital that he or she is willing to spend on quota, and this is included in the model.

In order to purchase additional quota for a particular period, a farmer must produce at least 125 per cent of the current quota allocation in one of the last three years. Therefore, if a producer buys extra quota they must qualify under this new quota level if they wish to purchase more quota in the next year (NSWDC 1990). Prices for quota transactions are 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 is the average price of quota for the specified period multiplied by the current real interest rate.

Several methods were used to verify the model and data included in it. After an initial model was constructed, the farmer was consulted who suggested several modifications which would make the model 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 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 show that increases in the variable costs of production eventually lead to a reduction in the amount of milk produced. This occurs because the marginal costs of increased production exceed the marginal returns from this production (Tozer 1991).

4. RESULTS

4.1 Fixed Quota Model Results

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 (see Table 1). This calving pattern is very different to the accepted norm of calving a constant number of cows in each period. The traditional pattern is accepted as it 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 is forced into the farm plan, the objective function value could be reduced by up to $67 per cow per period.

There is a very small band of allowable changes in the price of manufacturing milk before changes occur in the optimal solution. The range of this band is -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.

4.2 Transferable quota model results

To maximise TGM under the transferable quota scheme, cows should calve in periods six and nine. By doing this the farmer could achieve a TGM of $120 466 (see Table 1). Also, it is most profitable to purchase quota in periods two, eleven, twelve and thirteen, and sell quota in periods four and five.

The suggested plan contained several differences to that of the fixed quota model analysis. These were the periods in which the one of the two types of milk were not supplied, either to the NSWDC or to the manufacturer. No market milk is delivered in period five, and no manufacturing milk, other than that required for the safety margin, is supplied in periods two, eight, eleven and thirteen. These results indicate that in periods in which no milk of one type is sold, the marginal revenue from the other type exceeds the marginal costs of producing the second type of milk.

Table 1

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
Calve Cows TQ						32			88					120
Calve Cows FQ				47					73					120
Mkt. Milk TQ	27000	47942	27000	7167		27000	27000	27000	27000	27000	89940	30755	66863	431667
Mkt. Milk FQ	27000	27000	27000	27000	27000	27000	27000	27000	27000	27000	27000	27000	27000	351000
Man. Milk TQ	29831		13336	20550	23304	21958	2887		76019	73690		47308		308883
Man. Milk 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 would occur in the low cost quota periods of winter. This indicates that the returns from these quota purchases are more profitable than other quota purchases. Quota purchases are constrained by the expenditure and purchase maximums set by the NSWDC. Thus quota is purchased in periods with the highest returns. Quota is sold in periods with the highest selling price, or where the marginal costs of production exceed the marginal revenue of the output.

4.3 Further Analysis

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

In the fixed quota model the same quantity of quota is to be purchased and supplied in each period. The results of this analysis suggest that under the fixed quota scheme an extra quota of 26 722 litres per period is purchased, giving a market milk requirement in each period of 60 402 litres, for a total purchase amount of 347 386 litres (see Table 2). The purchase price for quota is assumed to be $15/L, which converts into an annual cost of $1.53 per litre. This price is the amount producers were charged in the last surrender pool allocation operated by the NSWDC.

Under the transferable quota scheme, it is optimal for the farmer to purchase an additional 372 202 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 34 837 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. This indicates that, enabling farmers to match milk supply to suit pasture growth patterns and times of relatively cheap feed supplies will result in increased returns and/or reduced costs. Hence, a likely outcome is an increase in efficiency of the dairy industry, at the farm level.

The proposed number of cows to be milked, and the suggested amount of grain to be purchased under the transferable scheme changed unexpectedly. Under the transferable scheme 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 (see Table 2). This would imply that the marginal revenue

Table 2

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
Calve Cows TQ		20		20	15	5	20		20		20		20	140
Calve Cows FQ	8	12	11	10	11	10	11	19	19	19	3	17	17	151
Mkt. Milk TQ	56885	60299	50944	61700	65830	65352	70547	63395	69634	62368	66986	59762	62615	816318
Mkt. Milk FQ	60402	60402	60402	60402	60402	60402	60402	60402	60402	60402	60402	60402	60402	785226
Man. Milk TQ														
Man. Milk 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	362197
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

from feeding grain at critical production stages exceeds the marginal costs of this grain.

One result which is similar in both models, was the area of lucerne sown for hay production. Both models suggest that all, or most, of the land available for lucerne rotations be used to produce lucerne hay, instead of that suggested in earlier results of using some of this area for lucerne-based pastures. This would seem to imply that feeding grain to cows provides higher nutritional value than grazing lucerne-based pastures, and the marginal costs of feeding grain are lower than the marginal costs of producing lucerne pastures. Also, the marginal revenue of lucerne hay production is greater than the marginal revenue of milk sales.

5. DISCUSSION OF RESULTS

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 show that the farmer can increase the TGM of his dairy activities by about $10 000, above the fixed quota situation, by trading in quota. This increase in TGM is achieved even though less milk is 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, a farmer 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.

If the possible returns from selling high priced quota exceeds the profit from the milk produced in any period, assuming the same marginal cost in every period, the farmer would be able to generate

more profit by selling this quota instead of supplying market milk. For example, the price for quota in period five is approximately 25 c/L and in period thirteen the average price is 12 c/L. Therefore the farmer could sell one litre of quota in period five and purchase two litres in period thirteen. Assuming constant marginal costs of production in every period the farmer could increase the returns of the dairy activity by the gross margin of this extra litre of quota milk. This implies that the farm would not become purely a manufacturing or market milk supplier, but a combination of both.

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 are far greater than the gross margin possible when operating within a fixed quota scheme. This occurs because farmers are 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 their dairy farm. This is in contrast to a farmer operating under a fixed quota scheme who must supply the same quantity of milk to the New South Wales Dairy Corporation each and every week.

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 102 000 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 in this research support the view that the economic efficiency of an industry increases when transferable quotas are used, rather than fixed quotas for supply control. This conclusion is reached after analysis of a case-study 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 or processors would fall as producers would seek to supply the market which yielded the highest returns, or producers seeking to leave the industry sold their quota to those remaining in the industry, who now produce manufacturing milk. Also, the demand for quota would increase as competition is less restricted, hence the price of quota may rise 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 before.

7. FURTHER RESEARCH

As the model developed in this study is a steady state, one-year representation of the case-study farm, no indication is 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, to provide a complete picture of the best method to achieve the optimal solution.

The model could be expanded to include time, as the producer may be able to attain a similar TGM, but only work on their 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.

REFERENCES

Davies,L. (1987), "Are feed grains worthwhile storing on-farm? Part 1. Feed grain price trends" Commodity Bulletin. 16(3) 26-28 New South Wales Department of Agriculture. Sydney.

Hunter Dairy Development Group. (1990), Preliminary Report Milk Producer Questionnaire Hunter Valley Development Group. Muswellbrook

Lembit,M., Topp,V.,Williamson,G. and Beare.S. (1988), "Gains from a negotiable milk quota scheme for New South Wales" Quarterly Review of the Rural Economy

Neutze,G.M. (1963), "Saleable city milk supply quotas" Australian Journal of Agricultural Economics 7(1),136-8.

New South Wales Agriculture and Fisheries. (1990), Challenge of Change New South Wales Agriculture and Fisheries. Sydney

New South Wales Dairy Corporation. (1990), Individual Quota Policy New South Wales Dairy Corporation. Sydney.

Parish,R.M. (1963), "On marketing quotas for fluid milk" Australian Journal of Agricultural Economics 7(1),61-8.

Small,A. (1988), "Interstate milk trade and its implications for the NSW dairy industry" Miscellaneous Bulletin No. 53 NSW Department of Agriculture. Sydney.

Tisdell,C.A. (1982), Microeconomics of Markets. John Wiley and Sons. Brisbane.

Tozer,P.R. (1991), On-Farm Impacts of Transferable Dairy Quotas: A Case Study. Unpublished Dissertation. University of New England. Armidale.

Williamson,G., Topp,V., Lembit,M. and Beare,S. (1988), Quota Regulations and Economic Efficiency in the New South Wales Dairy Industry: A Programming Evaluation Paper presented to the 1988 Australian Economics Congress,Canberra. August.